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FORTRAN INTERACTIVE
ROAD DESIGN

A Special Research Problem
Presented To
The Faculty of the School of Civil Engineering
Georgia Institute of Technology

By

Joseph P. Cuccu

In Partial Fulfillment
Of the Requirements for the Degree of
Master of Science in Civil Engineering

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ABSTRACT

This report provides a prototype computer program for the design of roads in an Amphibious Operations Area for the Marine Amphibious Force. The report is divided into two sections; the State of the Art Research, and the Road Design Program Development.

The State of the Art section of this research provides a background of military construction management programs developed for microprocessors. These are reviewed in the first five chapters: OVERVIEW, ARMY PROGRAMS, NAVY PROGRAMS, MARINE CORPS PROGRAMS, and GEORGIA TECH PROGRAMS. The State of the Art in relation to this research problem is the Road Design Program of LCDR R. R. Setzekorn.

The development of a Road Design computer program is the subject of the final two chapters: PROGRAM DESIGN and CONCLUSIONS. Here the design of a road is broken down into eight functional stages; Horizontal Alignment, Superelevation, Soils, Vertical Alignment, Cross Section, Intersection Points, Cross Sectional Area, and Mass Balance. These stages are, for the most part, based on procedures developed in Army Technical Manuals. However, some design methods from Surveying, by Harry Bouchard, et. al., and Highway Engineering 4e, by Paul H. Wright and Radnor J. Paquette; are also used. The flow charts and the final prototype computer program, Fortran Interactive Road Design (FIRD), were developed by the auther of this report. Input to this program is interactive with the user, and requires the use of the user's manual. Output is received after completion of each of the eight functional design stages.

ACKNOWLEDGEMENT

I wish to express my appreciation to my wife, Sherrie, for her contributions in the development of the flow charts. I also wish to express my gratitude to Ms. Marge McMullen, whose consummate secretarial skills produced this report.

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CHAPTER I

OVERVIEW

In any military conflict the capability of providing adequate construction support is a virtual necessity. Most of the design procedures for this construction support are well delineated by numerous Army, Navy, and Marine Field and Technical manuals. Unfortunately, in an actual battlefield situation, the military engineer will have little time to research these manuals to develop the required design. Foreseeing this, computer aided designs (CAD) have been developed for the use of the combat engineer.

Initial work on the development of computer aided designs for combat engineers began at the U.S. Army Engineer Center, Fort Belvoir, Virginia, in the 1960's. Their research evolved around the use of small rugged microcomputers that could be used by mobile engineering units. Though this research was later discontinued, recent improvements in microcomputers have renewed interest in computer aided designs that could be used at the Battalion Field Level.

In the 1970's the 20th Engineer Brigade of the XVII Airborne Corps at Ft. Bragg, North Carolina began development of programs for their microcomputer. The 20th Engineer Brigade tailored the programs developed by the Fort Belvoir School to meet their needs. In addition, the 20th Engineer Brigade developed their own software packages to aid their own personnel, security, and logistics

management needs, as well as their construction operations mission. Unfortunately the sensitivity of the 20th Engineer Brigade's microcomputer system is such that the current system cannot withstand field conditions.

The U.S. Army Signal Corps also began development of a microcomputer system in the early 1970's. The Electromagnetic Compatibility Analysis Center of the 35th Signal Brigade developed software to plan and manage communications-electronics (C-E) engineering systems in support of major field exercises. As with the 20th Engineer Brigade, the 35th Signal Brigade does not plan to deploy the microcomputer system due to the system's sensitivity.

The Naval Construction Force also procured a microcomputer system during the 1970's. Software programs, developed by the Civil Engineer Support Office (CESO), Port Hueneme, California was promulgated to each of the permanent deployment sites of the eight Naval Mobile Construction Battalions (NMCB). The computer programs developed to date include a CPM program, two personnel management programs, and programs for project material and tool inventory control. This microcomputer system, like the others, is for peacetime application only and is not part of the NMCB's table of allowance.

In 1974 the Marine Corps procured a hardened version of the IBM Series 1 microcomputer to automate processing of their administrative data. A software package, the Automated Data Processing Equipment-Fleet Marine Force (ADPE-FMF) program, was developed to efficiently transfer personnel, financial,

operational and logistical data from the battalion or divisional level to a centralized main frame computer. The ADPE-FMF program corrects data entries and stores them directly on a disk. This disk is then physically carried to the main frame computer site and read into the larger system's data bank. The ADPE-FMF system, though not oriented toward combat engineering, is the only active system currently considered deployable by the Armed Services.

Finally prototype programs, designed for microcomputer implementation by military engineers, have been developed by the Civil Engineering Laboratory, Port Hueneme, California and the Georgia Institute of Technology. One of these programs, "Computer Aided Road Design Procedures for Microprocessors" by Robert R. Setzekorn (see reference (1)) is an interactive program for the design of an improved road. It was written in Cyber 70 basic language. The design program developed herein is based on the research of LCDR Setzekorn. The intent of this research is to develop a Fortran IV prototype road design program which meets and extends the capabilities of the Setzekorn program.

CHAPTER II

ARMY CONSTRUCTION MANAGEMENT PROGRAMS

The first to recognize the construction problems peculiar to combat engineers was the U.S. Army Engineering Center, Fort Belvoir, Virginia. During the 1960's the school was provided a WANG 2200 VP microcomputer. Using this system, the school developed prototype programs in the Basic language to aid their combat engineering units. A listing of these programs and their capabilities is given by Appendix A.[2] This system was later abandoned by the school in as much as the computer system utilized was not rugged enough to operate under field conditions. Nevertheless recent improvements in microcomputers have renewed interest in computer aided designs that could be used at the Battalion Field level. In addition, the school is studying the possibility of using programmable hand held calculators with preprogrammed magnetic cards to be used at the company level or below. This system however, even if applied, will not be able to handle the vast majority of the construction design tasks required by Army Combat Engineering Units.

The 20th Engineer Brigade of the XVIII Airborne Corps at Ft. Bragg, North Carolina was also provided a WANG 2200 VP. In addition, the Brigade was given the Ft. Belvoir school's prototype programs, which the Brigade later tailored in order to meet their needs. Using the WANG system, the 20th Engineer

Brigade began development of their own computer aided designs. A listing of the 20th Engineer Brigade CADs is given by Appendix B. As noted on Appendix B, many of these programs do not deal with the Brigade's primary mission of combat engineering, but instead were developed to aid the unit's personnel, security, and logistic management effort. The 20th Engineer Brigade currently quarters its WANG computer system in a portable trailer. Though this trailer is a controlled environment, the WANG's sensitivity to damage by fine dust is such that the system cannot be deployed. Presently the 20th Engineer Brigade is attempting to replace the WANG system with a more rugged system.

The 35th Signal Brigade also began CAD development on a WANG 2200 VP during the 1970's. As the 35th Signal Brigade's primary mission deals with communications, their program development is not pertinent to this research. Nevertheless, it is of interest to note that the 35th Signal Brigade also feels the WANG 2200 VP computer system is too sensitive to operate under field conditions. Both the 20th Engineer Brigade and the 35th Signal Brigade are attempting to procure a new system rugged enough to be deployable. The system desired by both these units is the ONYX Z8002 microcomputer system.[2+3] This system is shown by Table 2.1. Nevertheless, as the systems will be procured independently there is no guarantee that either unit will actually get the desired system.

Another interesting program of the Army Signal Corps is the Army Tactical Frequency Engineering System (ATFES).[4] It's

TABLE 2.1

Computer System Components for the 20th Engineer Brigade and the 35th Signal Brigade

* ONYX Z8002 Micro computer with 128KB memory and 10 serial ports
* ONYX Magnetic tape controller
* 9-track tape drive formatter, 800/1600 BPI, 45 IPS
* Data Media VT-82, interactive terminals
* High speed printer
* Daisey printer/plotter

function will be to plan and manage communications in a manner similar to the 35th Signal Brigade's existing software package. The microcomputer system chosen for this program is given by Table 2.2.[4] The plan is to deploy this microcomputer system to four permanent deployment sites in Europe. This system promises to be even more effective in the future due to a tri-service commitment to standardize software and hardware for computer processing of telecommunications. This program, known as Joint Tactical Communications (TRI-TAC),[5] may even be extended to include our allies in NATO. The standardization of computer systems is an important step toward efficient use of our computer data bases.

TABLE 2.2

ATFES Pilot Program Hardware

* PDP 11/70 Processor 2/512 KB memory (RSX11M + operating system)
* RWM03 67MB disk drive
* TWE 16 9-track tape drive 800/1600 BPI, 45 IPS
* VT 100 Alphanumeric display and keyboard
* LP11-VA Line printer, 300 LPM
* LXY 11-AD Printer w/OCR capability
* LA 120 Character printer, 180 CPS
* TEKTRONIX 4027 color graphic display and keyboard
* VERSATEC 1200A Printer/plotter, 1000 LPM/200 DPI
* MODEM
* Encryption devices
* Teletypewriters

CHAPTER III

NAVY CONSTRUCTION MANAGEMENT PROGRAMS

In the 1970's the 31st Naval Construction Regiment (31st NCR) of the Naval Construction Force (NCF) began implementation of an automated construction management system to aid the construction planning of deployed construction battalions. By this system, each deployed battalion would submit arrow diagram CPM's of their primary construction projects to the 31st NCR for breakdown and input into a main frame computer at the Naval Construction Battalion Center,[6] Port Hueneme, California. A summarized output would then be shipped back to each construction battalion for review. Updating was handled in the same manner.

As this system proved untimely and inefficient, the Civil Engineering Support Office (CESO), Port Hueneme was tasked with development of a deployable microcomputer system to be used by the construction battalions. To this purpose the microcomputer system of Table 3.1 was purchased, and CESO began development of prototype programs.[7] Currently the following programs are available to deployed construction battalions:

1. Construction Management (CM-4) program
2. Material Liason Office program
3. People program
4. Medical program

TABLE 3.1

Naval Construction Force PDP 11/03

Minicomputer System Components

- LSI-11/2 CPU
- RT-11 64 K byte floppy disk-based system (with dual RX02's)
- Four channel Asynchronous serial line unit
- Bootstrap loader/diagnostic/terminator/ ROM module
- Nine slot box
- Hard disk subsystem with add on disk drive
- LA 38 DECwriter IV terminal
- VT 100 video terminal

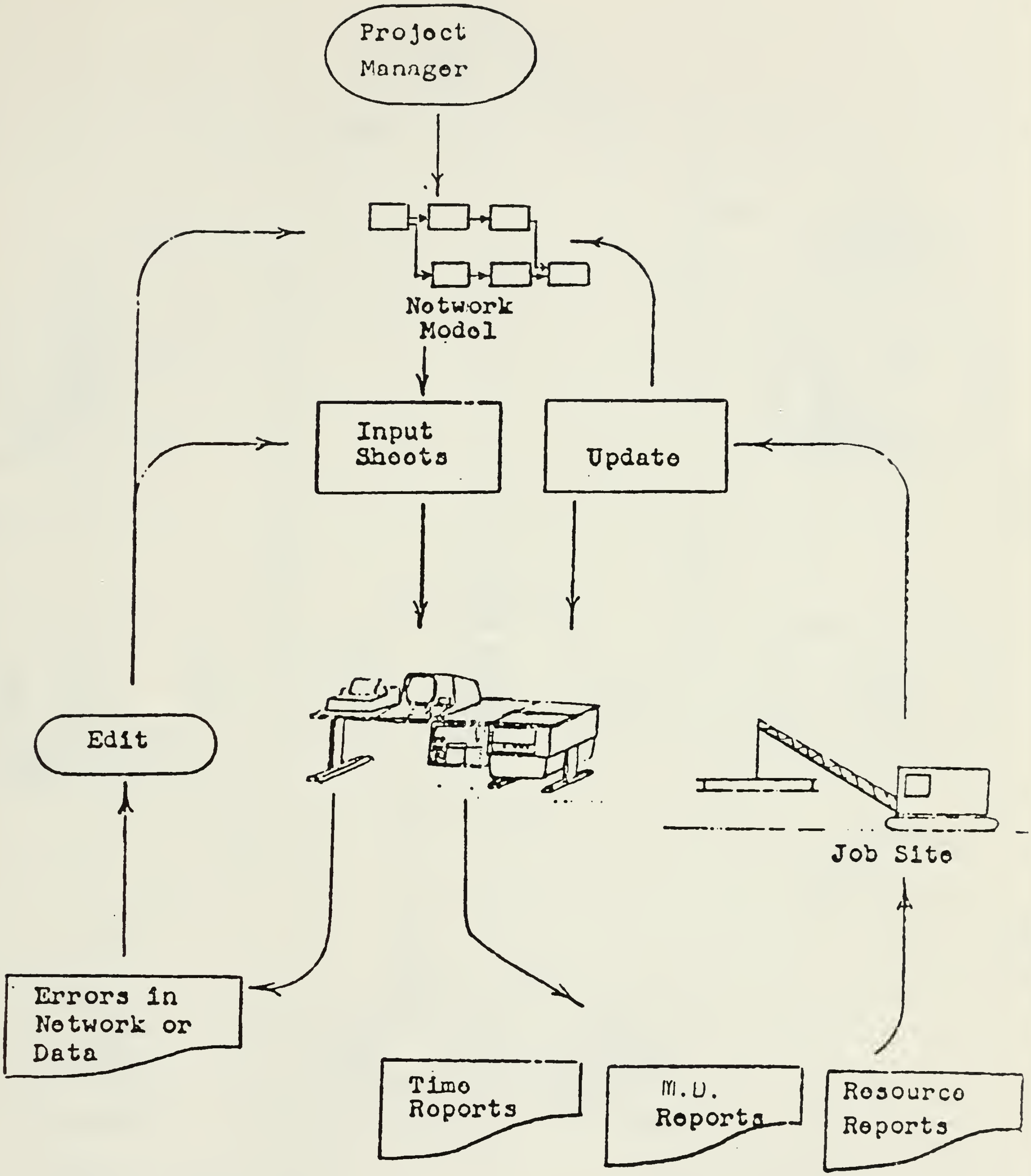
5. Tool program

Each of these programs were developed with interactive formating. They were designed so that even Seabees, without a programming background, could do the inputing. Nevertheless, both Construction Regiments have programs to train battalion personnel during each battalion's homeport (training) period.

The user of these programs responds to the computer's input data questions on a video display. The output reports are generated on a line printer. The output is then shipped to the Construction Regiments in monthly progress reports.

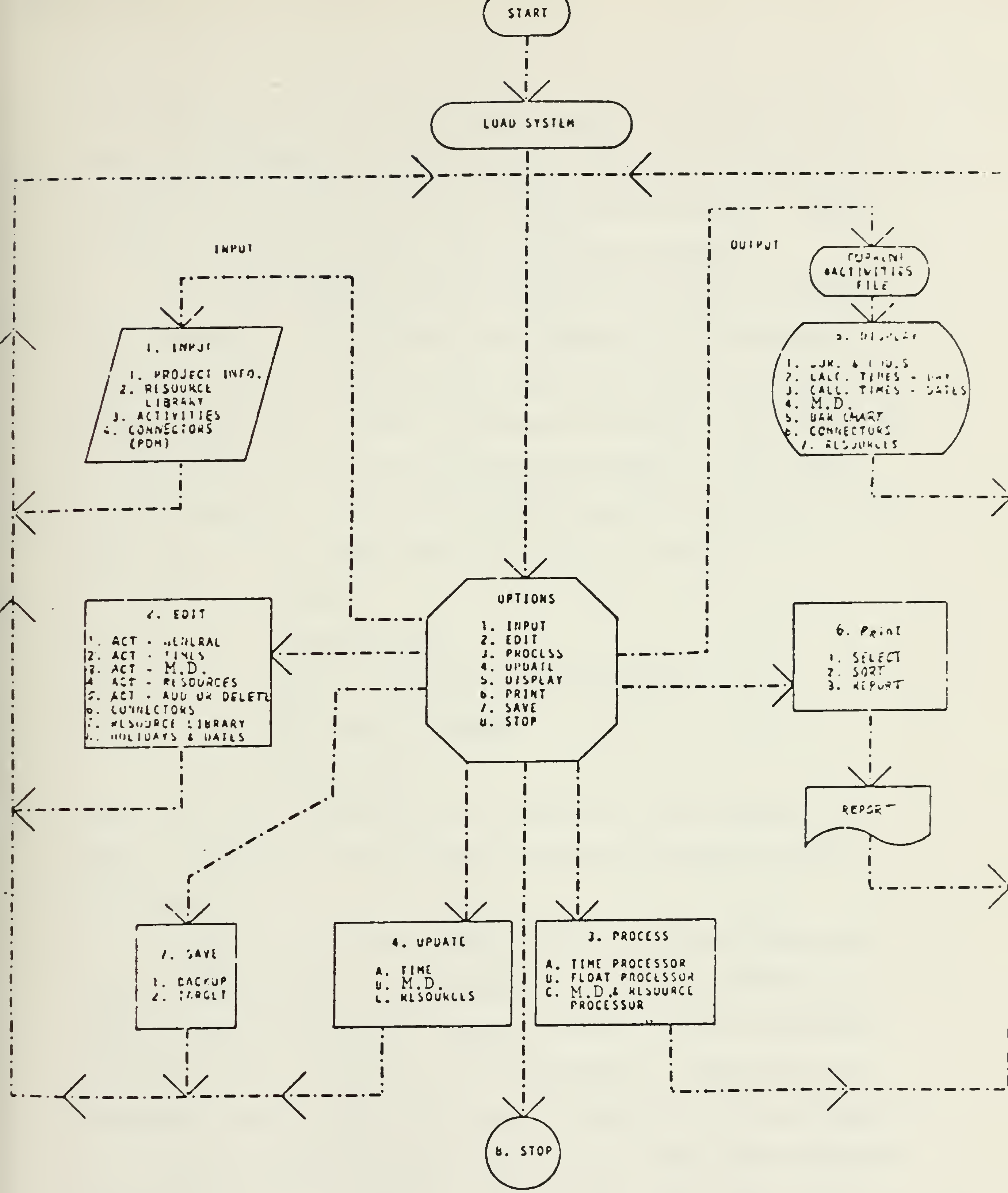
The Construction Management program was developed by Structural Programming, Inc. It is a basic network scheduling program capable of handling both arrow and precedence notation. The user can define a calendar and impose milestone date schedules on the network. Up to 99 resources can be assigned to any one network with up to six resources assigned to a specific activity. As resource balance, rather than cost control, is of the upmost concern to a battalion, the resource assignment allows for display of resource requirements. After input of the data, editing procedures are available to allow review and correction of the input data. A variety of line printer outputs is available from this program. The flow charts on this software package are given by Figures 3.2 and 3.3.[8]

The Material Liason Office (MLO) program allows the battalion to moniter and manage construction materials. The program inventories materials on site and on order, gives status of materials on order, and cross references these materials with



CM-4 System Flow Chart

Figure 3.2



CM-4 Program Flow Chart
Figure 3.3

the various projects. The program also has the capability of recording the demand of more common construction material requests so that proper inventory levels are maintained. Figures 3.4 and 3.5 give the flow charts for this program.[9]

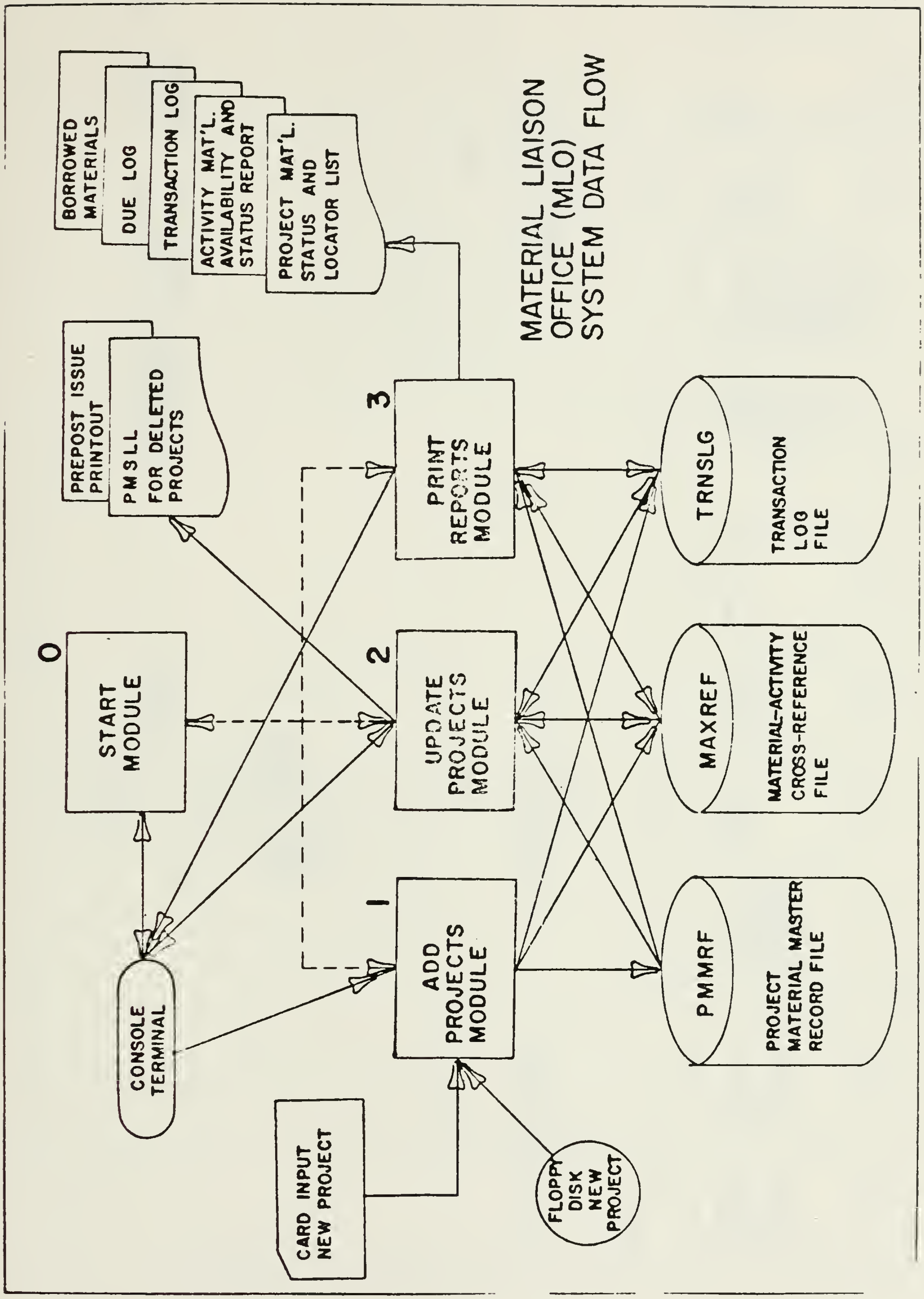
The People program was developed for management of battalion personnel. The program input consists of information on individuals such as name, social security number, address, paygrade, rate, date of birth, training and skills. Up to 24 items of data can be associated with each individual. The program output reports on this stored information sorted in up to nine data items. The program has five built in reports:

1. Roster
2. Address roster
3. Roster with PRCP (training) skills
4. PRCP skills summary
5. Short roster

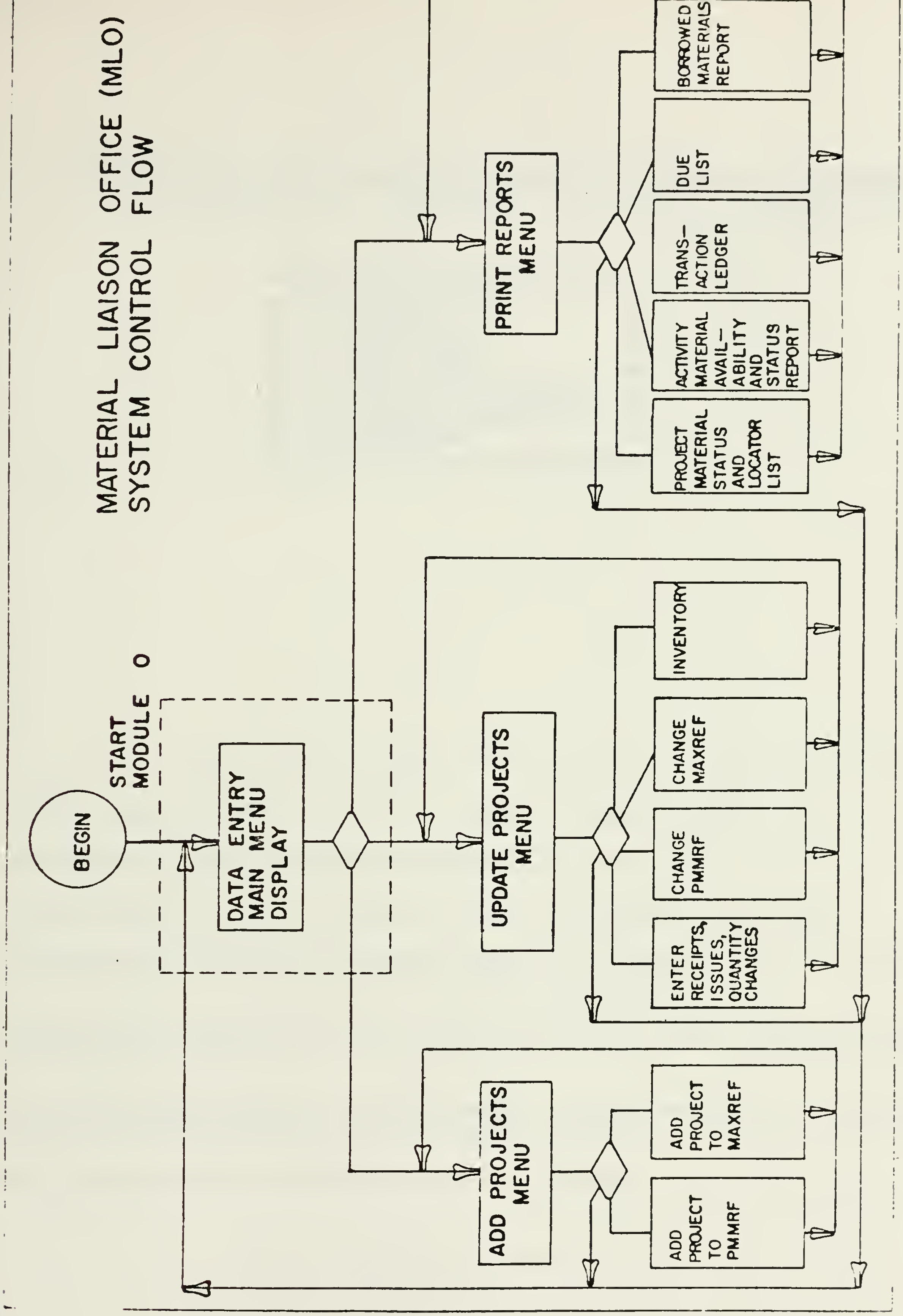
This data can be updated in the edit mode of the program. A menu of functions that the People program performs is given by Figure 3.6.[10]

The Medical program manages medical records of personnel within the battalion. The program stores such information as blood type, innoculations, medical examination and urinalysis testing on each individual in the battalion. There are four different output reports that can be generated by this program.[11]

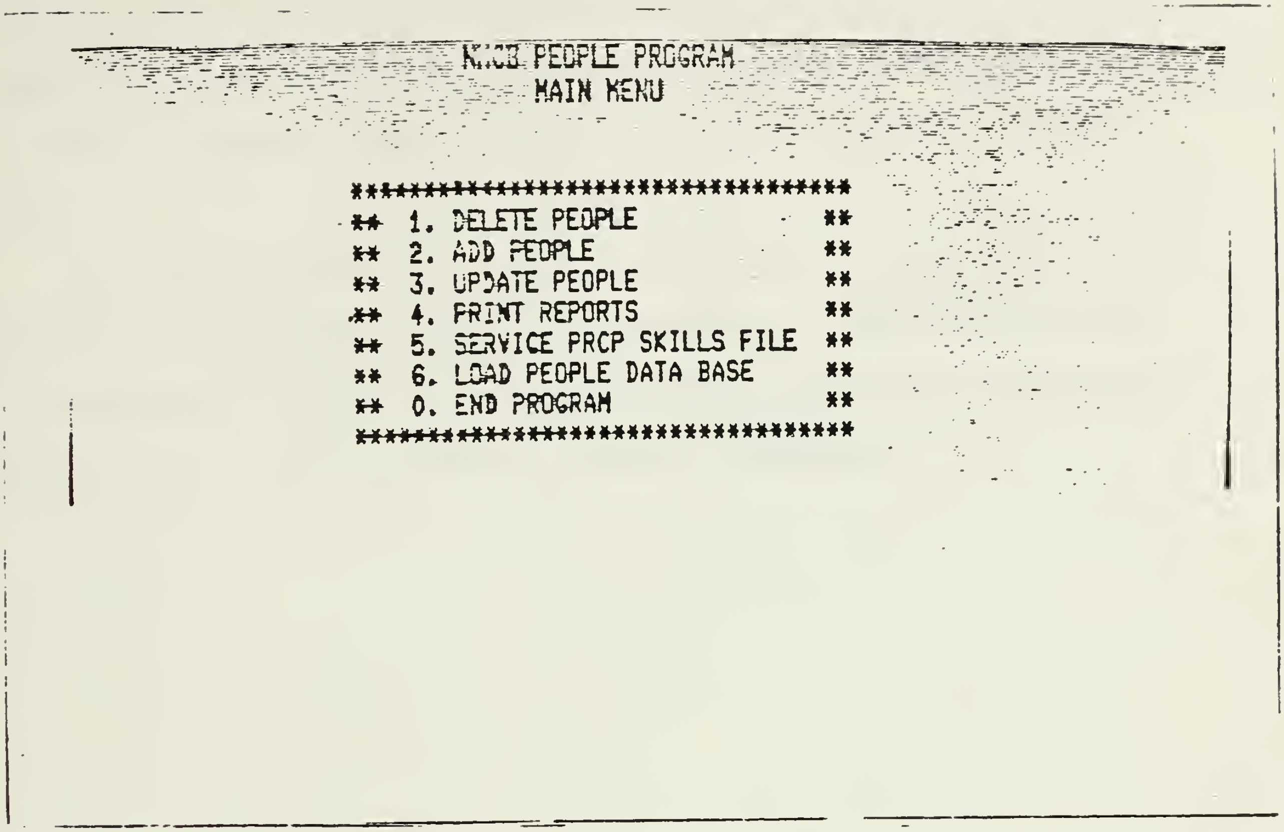
The Tool program manages the tool and small power equipment allowances for the battalion. Up to seven data items can be assigned to any specific tool. Data items include such infor-



MLO System Flow Chart
Figure 3.4


MATERIAL LIAISON OFFICE (MLO)
SYSTEM CONTROL FLOW
BEGIN
START MODULE 0
DATA ENTRY MAIN MENU DISPLAY
ADD PROJECTS MENU
ADD PROJECT TO PMMRF
ADD PROJECT TO MAXREF
UPDATE PROJECTS MENU
ENTER RECEIPTS, ISSUES, QUANTITY CHANGES
CHANGE PMMRF
CHANGE MAXREF
INVENTORY
PRINT REPORTS MENU
PROJECT MATERIAL STATUS AND LOCATOR LIST
ACTIVITY MATERIAL AVAIL-ABILITY AND STATUS REPORT
TRANS-ACTION LEDGER
DUE LIST
BORROWED MATERIALS REPORT

MLO Program Flow Chart
Figure 3.5



```
                    NMCB PEOPLE PROGRAM
                         MAIN MENU

         ************************************
         **  1. DELETE PEOPLE              **
         **  2. ADD PEOPLE                 **
         **  3. UPDATE PEOPLE              **
         **  4. PRINT REPORTS              **
         **  5. SERVICE PRCP SKILLS FILE   **
         **  6. LOAD PEOPLE DATA BASE      **
         **  0. END PROGRAM                **
         ************************************
```

Delete People provides the means to delete a record from the file.

Add People provides the means to add records to the file.

Update People provides the means to change information in a record.

Print Reports generates a hard copy report fo all data that is in the file. This report can be generated in sort sequences wanted.

Service PRCP Skills File provides the means to print, add, delete, or renumber the PRCP skills file.

Load People Data Base will transfer packed and unpacked data files (from GEMS) to unpacked format on hard disk or floppy diskette.

End Program provides the means to halt the program.

People Program Main Menu
Figure 3.6

mation as tool custody, last preventive maintenance and safety inspection, and condition. The output report lists the tools and data, flagging those tools overdue for custody or inspection.[12]

The Naval Construction Force is currently developing more programs to aid their construction effort. Nevertheless, due to the sensitivity of the microcomputer system, only peacetime applications of the system are being considered.

CHAPTER IV

MARINE CORPS PROGRAMS

Although not construction oriented, the Marine Corps has a hardened version of the IBM Series 1 microcomputer which they have used to automate processing of their adminsitrative data. The component make up of the IBM microcomputer system is shown by Figure 4.1.[13] The Automated Data Processing Equipment-Fleet Marine Force (ADPE-FMF)[13] softward package is used to efficiently transfer personnel, financial, operational and logistical data from each battalion's IBM microcomputer to a centralized main frame computer held at division headquarters. Battalion input data is entered into the microcomputer which stores this information on a disk. This disk is then physically shipped to the main frame computer site and read into the larger system's data bank.

Though this system sounds inefficient, a system quite similar to the Marine ADPE-FMF is currently under development by the Army. The Division Level Data Entry Device (DLDED)[14] program would put microcomputers on a company level so that administrative and logistical requirements of that unit could be inputed. This data would be stored by each microcomputer on a disk and either shipped to the main-frame computer or transmitted by the aforementioned TRI-TAC system. The Army feels that such a system could eventually support many different types of forward units, perhaps even engineering units. On the other hand, the

TABLE 4.1

ADPE-FMF Equipment Component Listing

1. IBM 4952 Central Processor Unit with 64K bytes of memory

2. IBM 4978 Display Station with 9 inch Video Screen and Keyboard

3. IBM 4974 Terminal prints 120 characters per second

*4. IBM 4469 Magnetic Tape Drive Unit

**5. IBM 4470 Paper Tape Punch

* Provided only to units requiring this type of interface.

** Provided to units embarked on Navy vessels to interface Navy communication equipment.

Marine Corps will concentrate its development of the ADPE-FMF system on administrative and operational needs.

The Marine Corps, however, is not insensitive to the needs of their combat engineering units, and is fully aware of the magnitude of both the construction and logistical support it will require during an amphibious operation.[15] To this purpose the Amphibious Logistic Support Ashore (ALSA) system was developed by the Marine Corps.

The ALSA system is structured to provide a continous stream of supplies, equipment and construction support to a Marine Amphibious Force (MAF) unit engaged in securing a hostile beachhead. The engineering units of a Marine Air/Around Task Force (MAATF) unit will utilize the ALSA system to provide the construction support. The primary construction requirement of the Marine Air/Around Task Force is the construction of the Amphibious Objective Area (AOA) or advanced base. This is no small feat. Minimum requirements of an AOA are as follows:

"1. Dependable main supply routes linking beach support areas (BSAs), logistic supply areas, ammunition storage points (ASPs), and combat troops.

2. Logistic supply areas for the storage, breakout and retrograding of containers and the storage of breakbulk supply items.

3. Ammunition supply points with protective earth revetments for the storage of sufficient quantities of ordinance to supply three Marine Air Groups and one Marine Division.

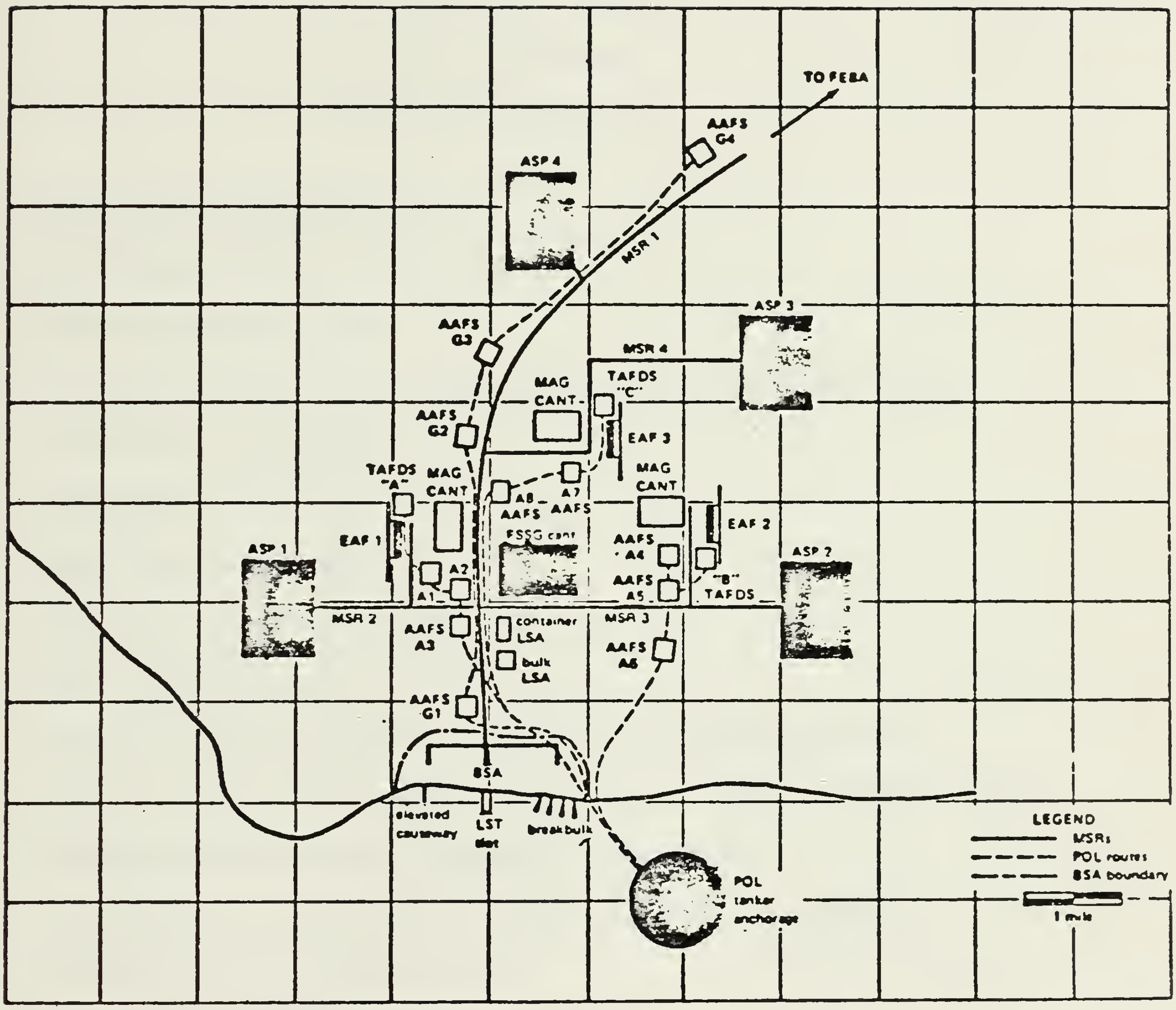
4. POL storage (AAFS), distributing and issuing systems (TAFDS, SIXCON).

5. Berthing, messing, administrative and work areas, and facilities to support 8,800 combat service support personnel assigned to the MAF Force Troops and 15,000 personnel assigned to the Marine Air Wing (MAW).

6. Expedient airfields to support the MAW (without benefit of existing facilities, at least three expeditionary airfields and several V/STOL and VTOL pads would have to be constructed to move the MAW ashore. A multitude of support facilities associated with these airfields must be available for the airfields to achieve a sustained operational capability.)"[16]

Figure 4.2[16] is a representation of a typical Amphibious Operations Area layout. Note that the AOA land requirements is almost 56 square miles. This tends to highlight the magnitude of the horizontal construction effort required of the MAGTF engineer.

The Marine Corps recognized that many of the separate construction tasks of its engineering units could be systematically designed and quantified. To this end the Civil Engineering Laboratory (CEL), Port Hueneme, California was tasked with a systems study of the MAGTF engineer's taskings.[17] Through this, CEL concluded that many of the separate construction tasks could be planned through the use of a small, portable computer system. Tables 4.3 and 4.4 [17] define those tasks that might be planned with computer aided designs. CEL is currently devel-



Typical AOA Layout

Figure 4.2

TABLE 4.3

U.S. MARINE CORPS

M.A.F. ENGINEER

MAJOR TYPES OF TASKS

1. ENGINEER RECONNAISSANCE
2. OBSTACLES AND/OR MINES BREACHING
3. DEMOLITION MISSIONS

* 4. OBSTACLE FABRICATION AND INSTALLATION OR POSITIONING

5. MINEFIELD CLEARANCE

* 6. MINEFIELD PLACEMENT

7. BOBYTRAP PLACEMENT
8. ROAD REPAIR AND MAINTENANCE

* 9. ROAD CONSTRUCTION

10. BRIDGE REINFORCEMENT - (OTHER THAN PREFABRICATED)
11. BRIDGE REPAIR AND MAINTENANCE (OTHER THAN PREFABRICATED)

*12. PREFABRICATED BRIDGE ERECTION (STANDARD)

*13. PREFABRICATED FLOATING BRIDGE ERECTION (STANDARD)

*14. TIMBER BRIDGE CONSTRUCTION

15. PREFABRICATED BRIDGE MAINTENANCE
16. BRIDGE REPLACEMENT (PREFAB. WITH SEMI-PERMANENT BRIDGING)

*17. RAFT CONSTRUCTION AND OPERATION

*18. EXPEDITIONARY AIRFIELD CONSTRUCTION

19. EXPEDITIONARY AIRFIELD MAINTENANCE

*20. HELICOPTER LANDING SITE AND ZONE PREPARATION

*These tasks are those which can be planned by computer.

TABLE 4.4

MAJOR TYPES OF TASKS

*21. POTABLE WATER SUPPLY INSTALLATION

*22. HYGIENIC SERVICES INSTALLATION

*23. ELECTRICAL SERVICES INSTALLATION

24. CUT AND COVER TYPE TEMPORARY FORTIFICATIONS CONSTRUCTION

*25. CAMP CONSTRUCTION

26. WAREHOUSE REPAIR AND MAINTENANCE

27. DRAINAGE SYSTEM CONSTRUCTION

28. DRAINAGE SYSTEM MAINTENANCE AND IMPROVEMENT

29. CAMOUFLAGE INSTALLATION

*30. FUEL STORAGE & DISTRIBUTION SYSTEM INSTALLATION

31. FUEL STORAGE & DISTRIBUTION SYSTEM INSTALLATION MAINTENANCE AND OPERATION

*These tasks are those which can be planned by computer.

oping a prototype software package of programs as part of its Development Engineering Planning (DEP) system. As part of this development process, CEL contracted with the Georgia Institute of Technology to study the existing level of development of MAF suitable design support systems and to propose methods for implementing design support systems in the MAF mission situation. The prototype microcomputer programs that evolved from this contract will be discussed in the next section.

The microcomputer system CEL is developing the DEP system on is the Tektronix 4052 Graphic System. CEL had previously used this hardware in the development of the Amphibious Objective Area Land Management System (AOALMS).

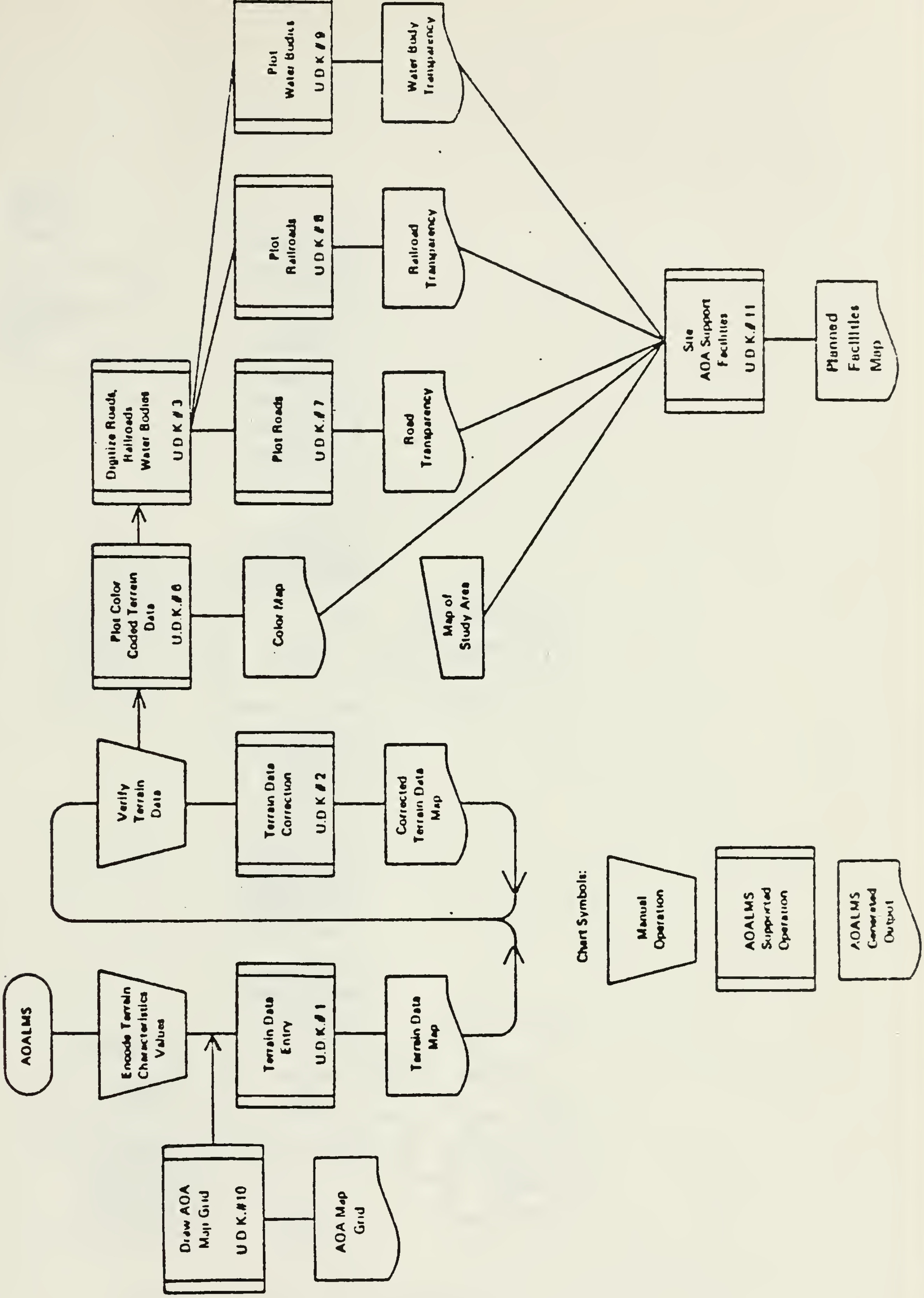
The AOALMS program was developed for the Marine Amphibious Force as a means of optimizing the siting of facilities for an advanced base.[18] The input data is the terrain characteristics (TC) of various sites within the AOA. These sites are divided into 500 m x 500 m square grids. Each square of the grid is then described by the three digits listed below:

1. Vegetation-density of its foliage (barren through jungle), (1=Bare, 2=Grass, 3=Brush, 4=Forest, 5=Jungle Urban).
2. Topology - contour (flat through cliffs), (1=Flat, 2=Rolling, 3=Hilly, 4=Cliffs).
3. Geotechnics - suitability of its soil for construction (good thin through bad), (1=Good thin, 2=Good thick, 3=Bad).

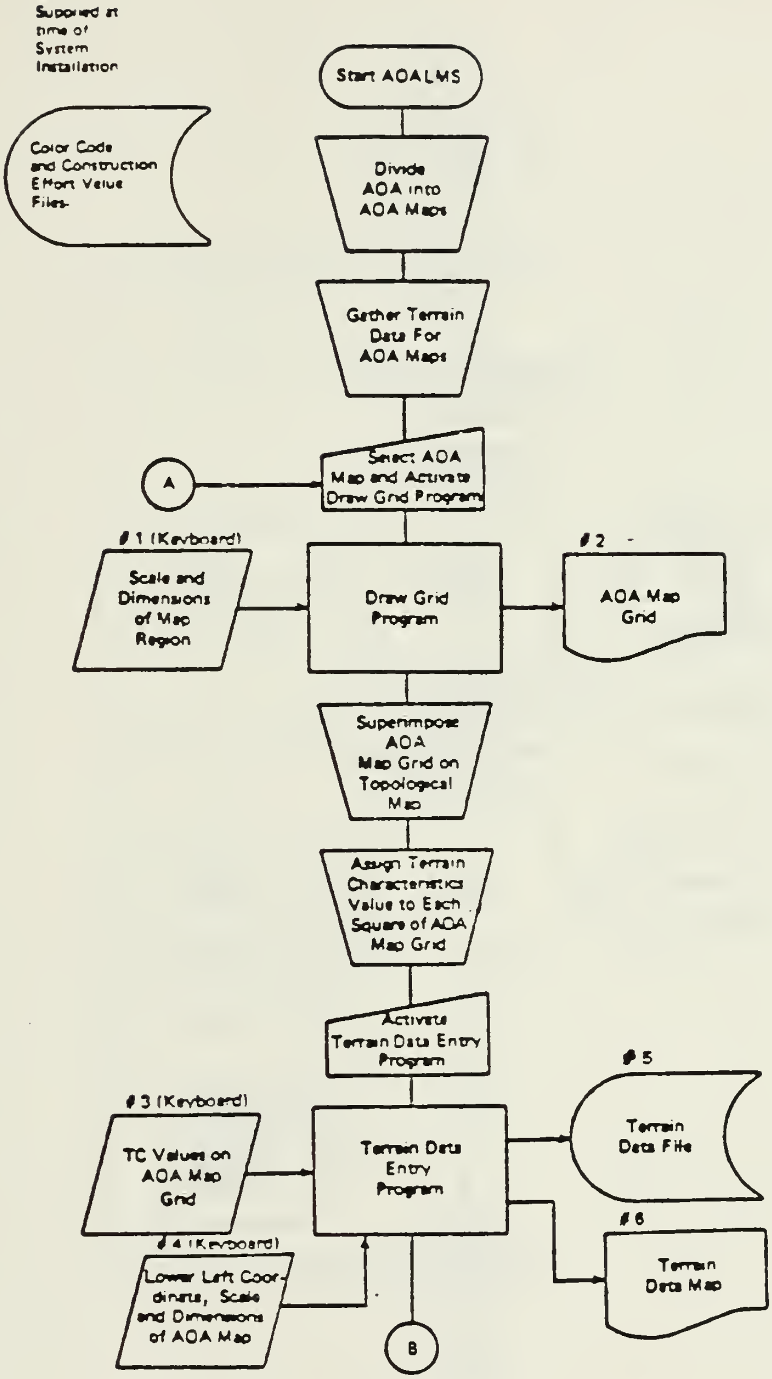
These three digits define the TC of each grid square, and must be manually input to the microcomputer. The AOALMS program evaluates the construction effort (CE) for construction of the various types of facilities based on the TC values for those grid squares. This CE value is the amount of man-days required to complete stripping, clearing, grading, and alike for that particular grid. The various types of facilities that are considered are: Expeditionary Airfield (EAF), Logistic Support Area (LSA), Ammunition Supply Point (ASP), Airfield of Varying Length (AIR), and Petroleum-Oil-Lubricant Facility (POL).

Finally, salient geographical features such as roads, rivers, and railroads are entered into the data base; along with the proposed location of each type of facility. Up to three different proposed locations or orientations is permitted for each facility type. The AOALMS program outputs the construction effort required for each proposed facility site. The user picks the optimal site based on the CE criteria. When all sites have been chosen the program adds up the total construction effort required for the AOA. Figures 4.5 through 4.9[18] define a flow chart of this process.

The full Tektronix system is shown by Table 4.10[18]. It is felt that a modified version of the Tektronix system would be suitable for both the DEP and ADALM systems. The Marine Corps is expected to procure this system in the near future.

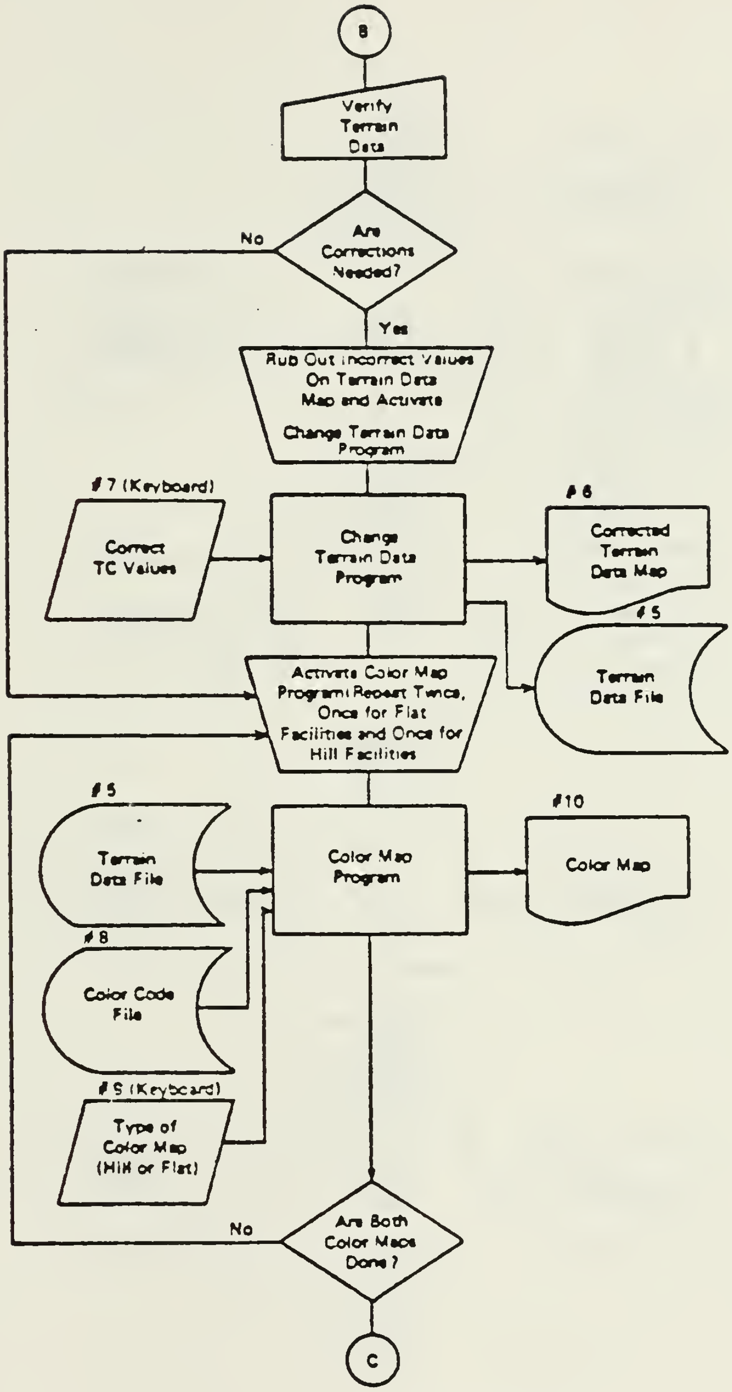

AOALMS
Encode Terrain Characteristics Values
Terrain Data Entry U.D.K.#1
Terrain Data Map
Draw AOA Map Grid U D K.#10
AOA Map Grid
Verify Terrain Data
Terrain Data Correction U.D.K #2
Corrected Terrain Data Map
Plot Color Coded Terrain Data U.D.K.#6
Color Map
Map of Study Area
Digitize Roads, Railroads, Water Bodies U D K #3
Plot Roads U D K #7
Road Transparency
Plot Railroads U D K #8
Railroad Transparency
Plot Water Bodies U D K #9
Water Body Transparency
Site AOA Support Facilities U D K #11
Planned Facilities Map
Chart Symbols:
Manual Operation
AOALMS Supported Operation
AOALMS Generated Output

AOALMS System Flow Chart
Figure 4.5


Supplied at time of System Installation
Color Code and Construction Effort Value Files.
Start AOALMS
Divide AOA into AOA Maps
Gather Terrain Data For AOA Maps
A
Select AOA Map and Activate Draw Grid Program
# 1 (Keyboard)
Scale and Dimensions of Map Region
Draw Grid Program
# 2
AOA Map Grid
Superimpose AOA Map Grid on Topological Map
Assign Terrain Characteristics Value to Each Square of AOA Map Grid
Activate Terrain Data Entry Program
# 3 (Keyboard)
TC Values on AOA Map Grid
Terrain Data Entry Program
# 5
Terrain Data File
# 6
Terrain Data Map
# 4 (Keyboard)
Lower Left Coordinates, Scale and Dimensions of AOA Map
B

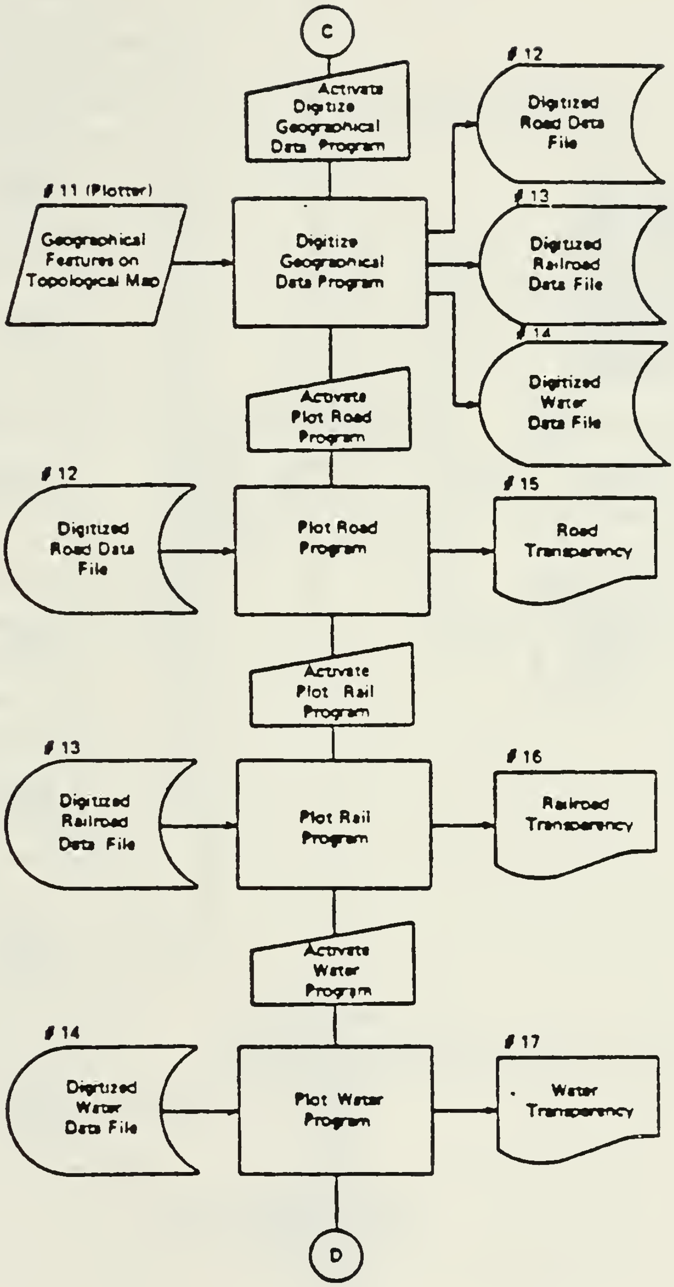
AOALMS System Flow Chart

Figure 4.6


B
Verify Terrain Data
Are Corrections Needed?
No
Yes
Rub Out Incorrect Values On Terrain Data Map and Activate Change Terrain Data Program
#7 (Keyboard)
Correct TC Values
Change Terrain Data Program
#6
Corrected Terrain Data Map
#5
Terrain Data File
Activate Color Map Program, Repeat Twice, Once for Flat Facilities and Once for Hill Facilities
#5
Terrain Data File
#8
Color Code File
#5 (Keyboard)
Type of Color Map (Hill or Flat)
Color Map Program
#10
Color Map
No
Are Both Color Maps Done?
C

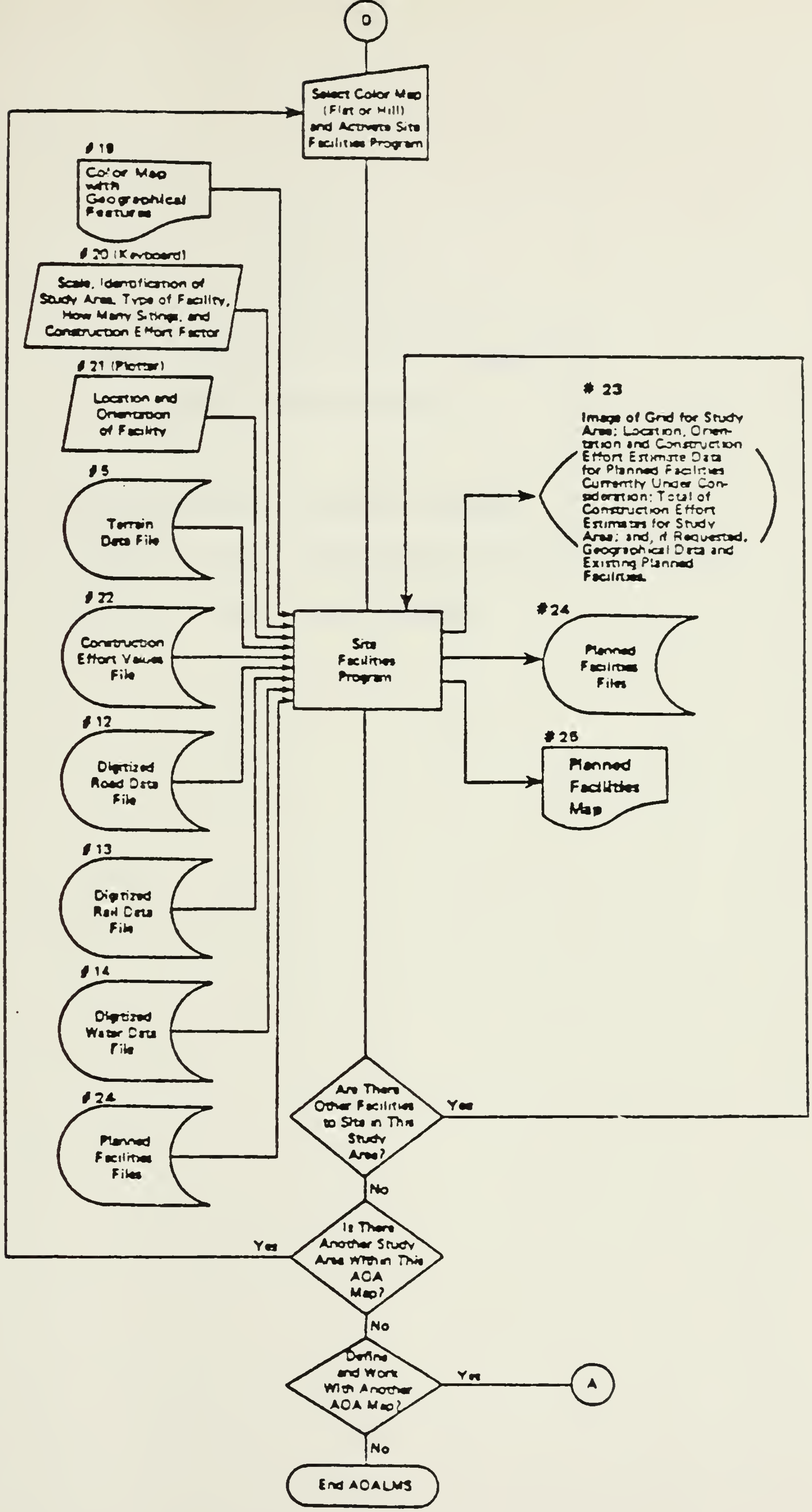
AOALMS System Flow Chart

Figure 4.7


C
Activate Digitize Geographical Data Program
# 12
Digitized Road Data File
# 11 (Plotter)
Geographical Features on Topological Map
Digitize Geographical Data Program
# 13
Digitized Railroad Data File
# 14
Digitized Water Data File
Activate Plot Road Program
# 12
Digitized Road Data File
Plot Road Program
# 15
Road Transparency
Activate Plot Rail Program
# 13
Digitized Railroad Data File
Plot Rail Program
# 16
Railroad Transparency
Activate Water Program
# 14
Digitized Water Data File
Plot Water Program
# 17
Water Transparency
D

AOALMS System Flow Chart

Figure 4.8


D
Select Color Map (Flat or Hill) and Activate Site Facilities Program
# 19
Color Map with Geographical Features
# 20 (Keyboard)
Scale, Identification of Study Area, Type of Facility, How Many Sitings, and Construction Effort Factor
# 21 (Plotter)
Location and Orientation of Facility
# 5
Terrain Data File
# 22
Construction Effort Values File
# 12
Digitized Road Data File
# 13
Digitized Rail Data File
# 14
Digitized Water Data File
# 24
Planned Facilities Files
Site Facilities Program
# 23
Image of Grid for Study Area: Location, Orientation and Construction Effort Estimate Data for Planned Facilities Currently Under Consideration: Total of Construction Effort Estimates for Study Area; and, if Requested, Geographical Data and Existing Planned Facilities.
# 24
Planned Facilities Files
# 25
Planned Facilities Map
Are There Other Facilities to Site in This Study Area?
Yes
No
Is There Another Study Area Within This AOA Map?
Yes
No
Define and Work With Another AOA Map?
Yes
A
No
End AOALMS

AOALMS System Flow Chart

Figure 4.9

TABLE 4.10

Proposed Computer System Components
For MAF Engineers

- Tektronix 4052 Graphic System
- Tektronix 4662 Interactive Digital Plotter
- Tektronix 4907 File Manager

CHAPTER V

GEORGIA INSTITUTE OF TECHNOLOGY CONSTRUCTION MANAGEMENT PROGRAMS

As previously discussed, many of the prototype programs developed by the Georgia Institute of Technology came about as a result of research performed for the Civil Engineering Laboratory. This contract was not the total source however. A most notable exception is the Water Points program developed by Monty Anderson for his Master's thesis.

In "A Prototype Decision Support System for the Location of Military Water Points"[19] Anderson utilizes operations research techniques to optimize the siting of proposed water resupply points based on the locations and quantities of both the water supply points and the demand points. Anderson saw this problem as one ideally suited to a microcomputer environment, and developed the program on a Chromatics CA-1999 color graphic microcomputer. His method of input is in itself rather unique as it utilizes both keyed data and graphic interactive input by the use of a light pen. The user initializes data by keying in unit demands and water point capacities. The road network linking the units with the supply points is then generated using a bit pad and digitizer. Finally the light pen is utilized to mark the water point locations and the units to be supported. These are indicated as nodes along the road network.

The user then manipulates the water allocations by making light pen "hits" to the program menu items or points appearing on the color monitor representing supply points or unit locations. In this manner the program defines the shortest distance to each unit from the water points and allocates the water supply to the units so that the distance travelled is minimized.

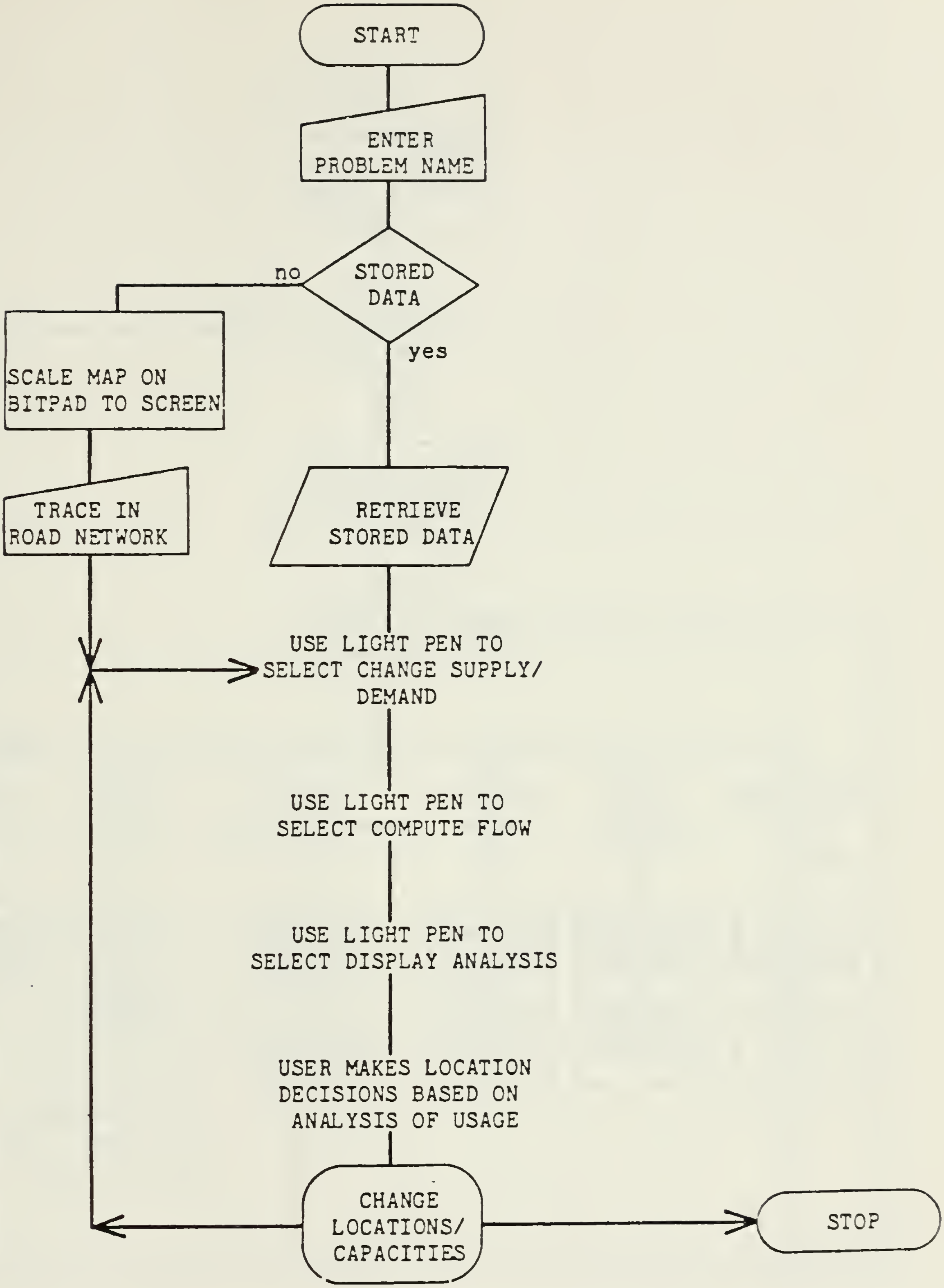
The use of graphical displays in the formulation of the problem and a user manipulated light pen in the problem's solution appears to be an ideal method for interactive user interface. As the user "sees" where his resources are over or under utilized and can change the allocation with a flick of the light pen, analysis of many different distributions can be accomplished in a relatively short time. Even more important, the user can more clearly understand the problem when a graphical display is used.

The system can generate four different graphical reports to aid the user's decision in the reallocation process. They are:

1. Gallons supplied vs Site #
2. Distance travel per gallon vs Site #
3. Actual distance travelled vs Unit #
4. Distance travel vs Alternate Water Point assigned.

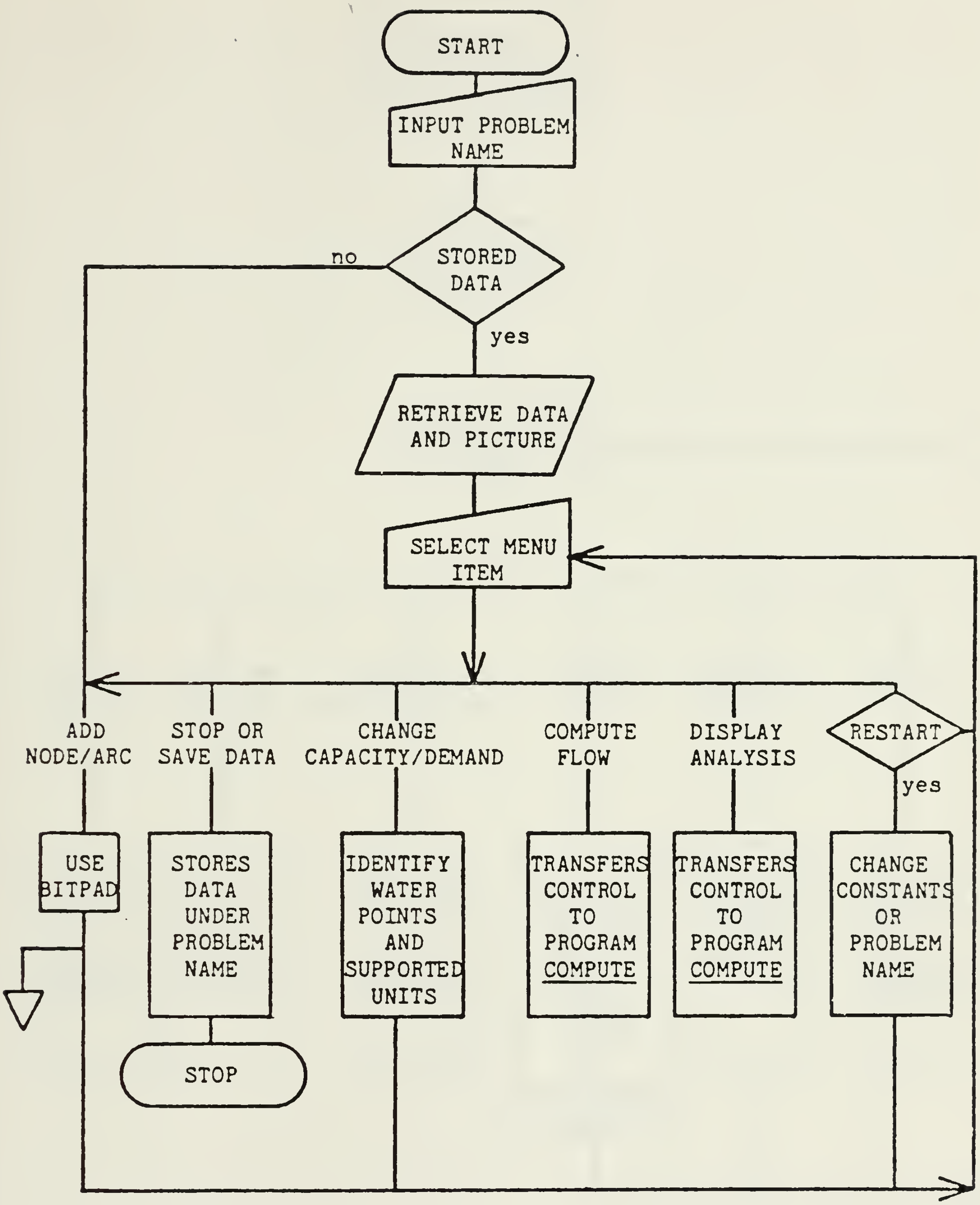
In addition, numerical data is available in each of the four graphical reports. Figure 5.1 shows a flow chart of user activities in manipulating this program. Figures 5.2 and 5.3[19] are flow charts of the program's two main subroutines.

Another notable effort in the development of computer aided


START
ENTER PROBLEM NAME
STORED DATA
no
yes
SCALE MAP ON BITPAD TO SCREEN
TRACE IN ROAD NETWORK
RETRIEVE STORED DATA
USE LIGHT PEN TO SELECT CHANGE SUPPLY/ DEMAND
USE LIGHT PEN TO SELECT COMPUTE FLOW
USE LIGHT PEN TO SELECT DISPLAY ANALYSIS
USER MAKES LOCATION DECISIONS BASED ON ANALYSIS OF USAGE
CHANGE LOCATIONS/ CAPACITIES
STOP

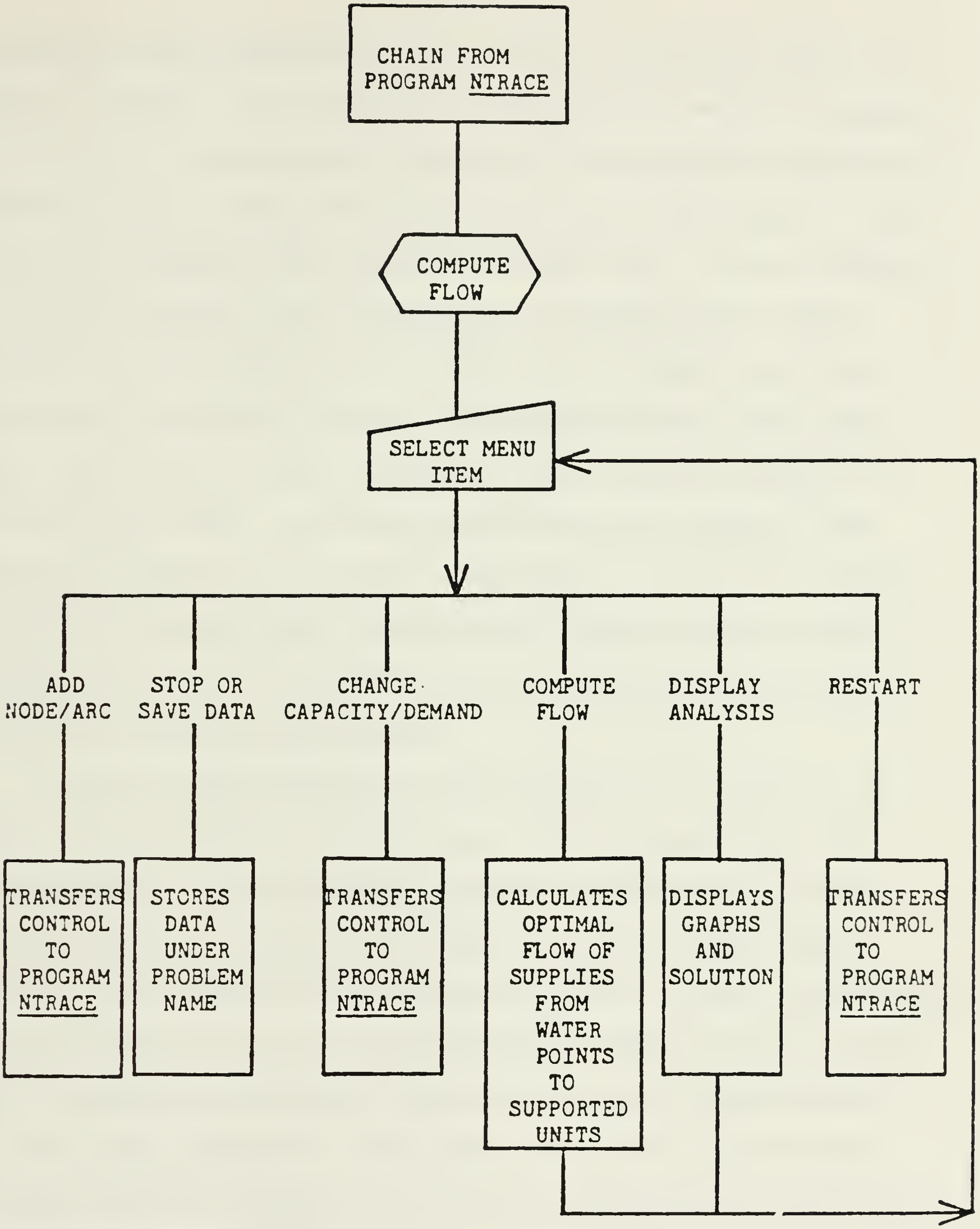
Water Points Flow Chart

Figure 5.1


START
INPUT PROBLEM NAME
STORED DATA
no
yes
RETRIEVE DATA AND PICTURE
SELECT MENU ITEM
ADD NODE/ARC
STOP OR SAVE DATA
CHANGE CAPACITY/DEMAND
COMPUTE FLOW
DISPLAY ANALYSIS
RESTART
yes
USE BITPAD
STORES DATA UNDER PROBLEM NAME
STOP
IDENTIFY WATER POINTS AND SUPPORTED UNITS
TRANSFERS CONTROL TO PROGRAM COMPUTE
TRANSFERS CONTROL TO PROGRAM COMPUTE
CHANGE CONSTANTS OR PROBLEM NAME

Subroutine NTRACE Flow Chart

Figure 5.2


CHAIN FROM PROGRAM NTRACE
COMPUTE FLOW
SELECT MENU ITEM
ADD NODE/ARC
STOP OR SAVE DATA
CHANGE CAPACITY/DEMAND
COMPUTE FLOW
DISPLAY ANALYSIS
RESTART
TRANSFERS CONTROL TO PROGRAM NTRACE
STORES DATA UNDER PROBLEM NAME
TRANSFERS CONTROL TO PROGRAM NTRACE
CALCULATES OPTIMAL FLOW OF SUPPLIES FROM WATER POINTS TO SUPPORTED UNITS
DISPLAYS GRAPHS AND SOLUTION
TRANSFERS CONTROL TO PROGRAM NTRACE

Subroutine Computer Flow Chart

Figure 5.3

designs for microcomputers is the special research problem of Dwight S. Durham. In the "Use of Computerized Network Analysis Systems on U.S. Army Corps of Engineers' Construction Projects"[20], Durham develops a small precedence notation CPM program. This program was written for interactive input mode. Input consists of activity number, title, following activities, and "work division". Work division is a code used to selectively sort various activities for output. The output report gives early start, late start, early finish, and late finish workdays, as well as total float. Critical activities are flagged. The program can handle up to fifty activities at one time. Durham modeled his program after the CYCLONE * GAME program of reference(21), using selective portions of the HGAME file to produce a simplified networking program.

"Computer Aided Design for MAF Engineers"[22] by Dr. D. W. Halpin was the impetus for the many of the recent CAD's for microcomputers. It was written as an investigation into the existing level of development of MAF suitable design support systems. Civil Engineering Laboratory, Port Hueneme, commissioned this study as part of its research for the DEP system. As part of this study two of the MAF engineering tasks were developed into prototype programs. The tasks chosen were prefabricated floating bridging design, and helicopter landing site and zone preparation design.

The Prefabricated Floating Bridge program was based on design procedures described in the Army River Crossings and Bridging Manuals (Field Manual 90-13 and Technical Manual 5-210).

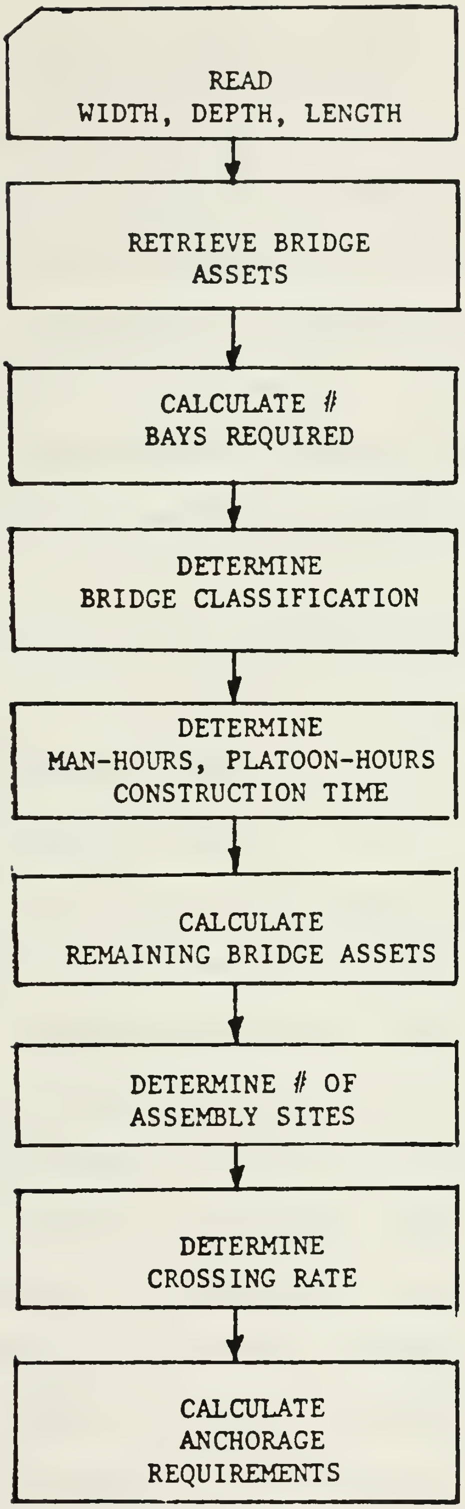
The design is for the most common types of floating bridges: Mobile Assault Bridge, Ribbon Bridge, and M4T6 Bridge. Input to the program is interactive with the user. Typical input information is as follows:

1. Availability of bridging assets
2. River width, depth, and current velocity
3. River bank height, slope, and soil CBR
4. Type of bridge to be built (one or any combination of bridge types)
5. Conditions under which the bridge is to be built (night or day).

The program then evaluates the site for design. This evaluation includes a feasibility study of the type of bridge to be used, with the program offering alternate methods of river crossing if appropriate. With valid input, the programs output report provides the following information:

1. River data (width, depth, and velocity)
2. Bridge classification (wheeled and tracked)
3. Crossing rate (vehicles per hour)
4. Bridge construction time (Platoon and/or Company Hours)
5. Required number of assembly sites
6. Required bridge assets
7. Remaining bridge assets
8. Any special requirements
9. Anchorage requirements

Figure 5.4[22] shows a macro flow chart of this program.


READ
WIDTH, DEPTH, LENGTH
RETRIEVE BRIDGE ASSETS
CALCULATE # BAYS REQUIRED
DETERMINE BRIDGE CLASSIFICATION
DETERMINE MAN-HOURS, PLATOON-HOURS CONSTRUCTION TIME
CALCULATE REMAINING BRIDGE ASSETS
DETERMINE # OF ASSEMBLY SITES
DETERMINE CROSSING RATE
CALCULATE ANCHORAGE REQUIREMENTS

Prefabricated Floating Bridge Program Flow Chart

Figure 5.4

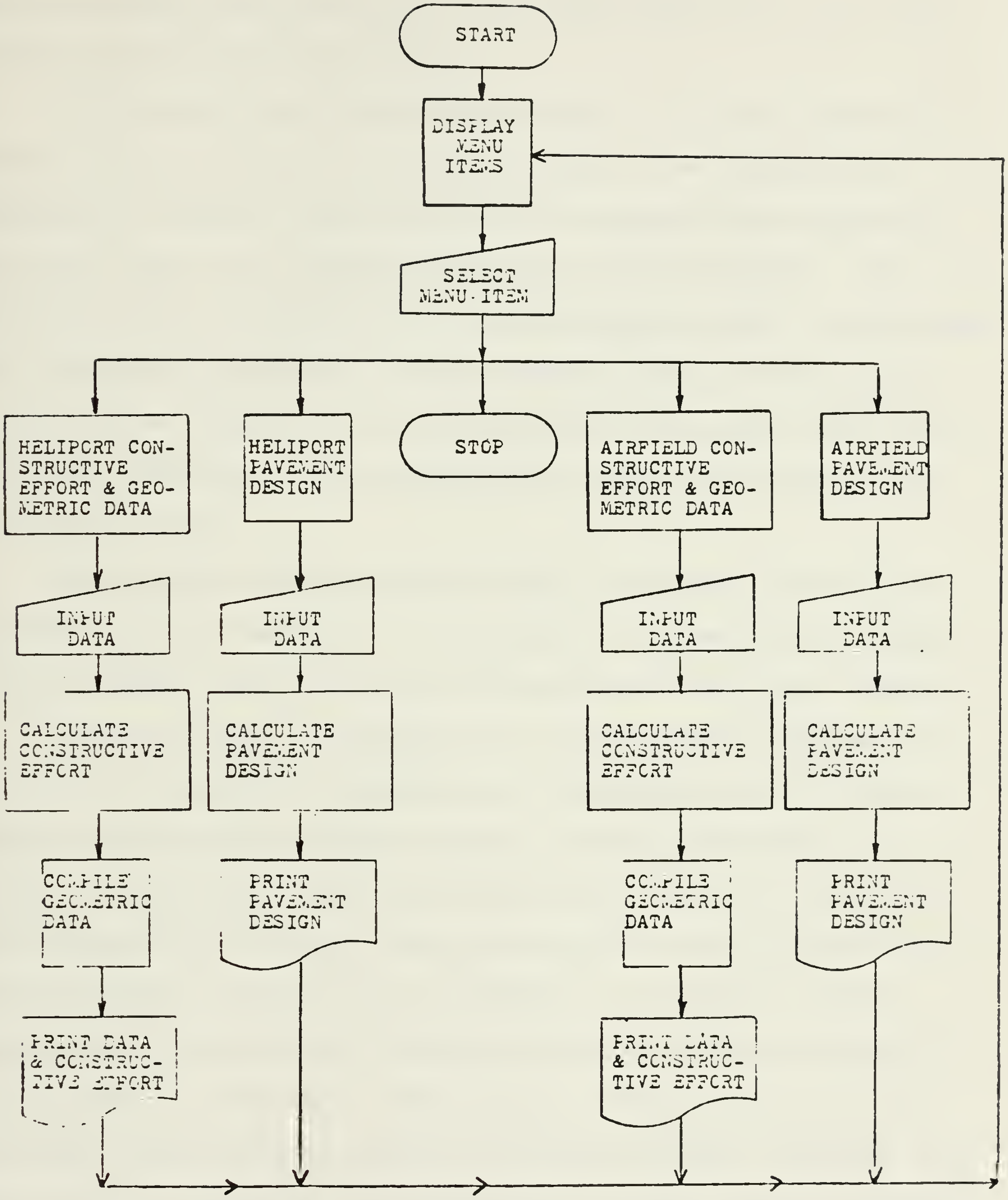
The helicopter landing site program developed under the Computer Aided Design for MAF Engineers study was later expanded into a special research project. In "Computer-Aided Design of Heliports and Expeditionary Airfields in the Amphibious Operations Area",[4] Hambrock develops a prototype program for the selection of an optimum airfield site. In addition, the program provides final layout and pavement design data.

The design of this program was divided into four basic functions:

1. Heliport Constructive Effort and Geometric Data
2. Airfield Constructive Effort and Geometric Data
3. Heliport Pavement Design
4. Airfield Pavement Design

This is described by the macro flow chart of Figure 5.5.[4] Input information is gathered by interactive input with the user. Input common to all functions include: the site's soil type, soil condition, soil thickness, vegetation, terrain slope characteristics, expected number of cycles of aircraft/helicopter operations, airfield index of subgrade, CBR of subgrade, CBR of base, CBR of subbase (if applicable), and construction force employed. In the case of a heliport design, additional information such as the number and type of helicopters, and the configuration of the field need to be inputed. The airfield design requires temperature, runway gradient, elevation of runway, and elevation adjustment factor data to be inputed for the runway length calculations.

The program's design of the runway is based on the U.S.


START
DISPLAY MENU ITEMS
SELECT MENU ITEM
HELIPORT CONSTRUCTIVE EFFORT & GEOMETRIC DATA
HELIPORT PAVEMENT DESIGN
STOP
AIRFIELD CONSTRUCTIVE EFFORT & GEOMETRIC DATA
AIRFIELD PAVEMENT DESIGN
INPUT DATA
INPUT DATA
INPUT DATA
INPUT DATA
CALCULATE CONSTRUCTIVE EFFORT
CALCULATE PAVEMENT DESIGN
CALCULATE CONSTRUCTIVE EFFORT
CALCULATE PAVEMENT DESIGN
COMPILE GEOMETRIC DATA
PRINT PAVEMENT DESIGN
COMPILE GEOMETRIC DATA
PRINT PAVEMENT DESIGN
PRINT DATA & CONSTRUCTIVE EFFORT
PRINT DATA & CONSTRUCTIVE EFFORT

Helicopter Landing Site Program Flow Chart
Figure 5.5

Army Technical Manual TM5-330,[23] and LCDR Hambrock's own field experience with airfield design.

The output is in a narrative format. Only the geometric design of the airfield is in tabular form. For the Heliport designs the typical output would be the landing pad dimensions, shoulder sizes, and approach/departure zone dimensions. The airfield output consists of the runway length, width, longitudinal and transverse gradients; taxiway length, width and gradients; parking apron length, width and gradients; clearance zones; overrun area dimensions; approach/departure zone requirements; and seperation zones.

The pavement design output format is common to both heliport and airfield designs. It consists of pavement type, thickness of design layers, and basic quantities of materials needed.

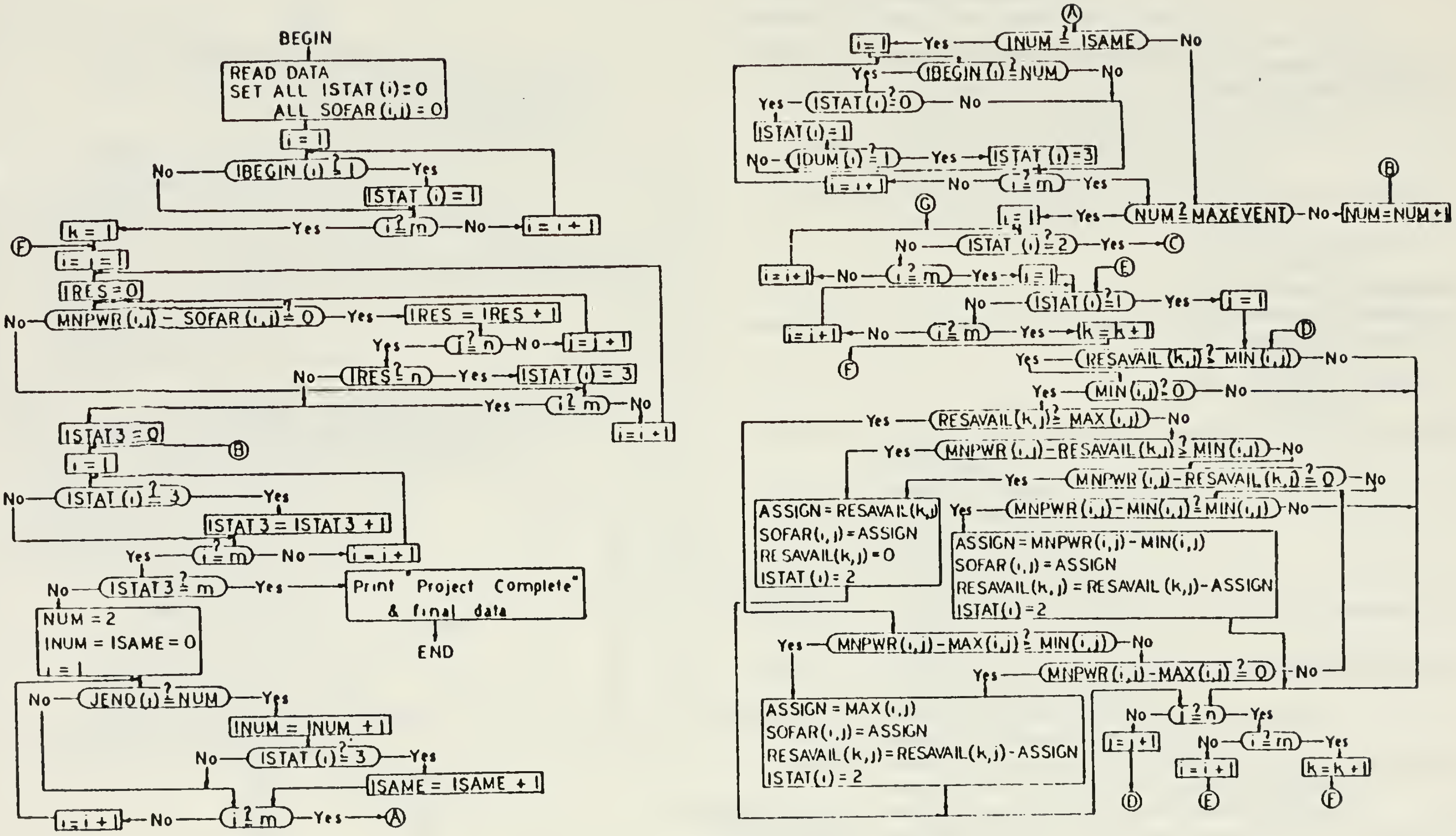
Another program developed for use by the MAF engineer is part of the "Equipment Estimating and Scheduling for the Marine Amphibious Force"[24] special research project, developed by Lt. D. Pruett. MAFESS (MAF Equipment Scheduling System) is a scheduling program which utilizes basic network input and equipment requirements for each activity, to develop a "crashed" network governed by the duration of these activities and the availability of equipment on each day. The program utilizes the Bennett algorithm to perform the crashing mechanism and Rood equipment selection cards to estimate the productivity of the various equipment alternatives. MAFESS is a prototype program based on modified version of FLEET, a computer program developed by R. Morrison at the Georgia Institute of Technology.

The input is in the interactive format, with the user describing the quantity and conditions under which the work activities are to be performed. The ROOD equipment card data base converts this information into required "resource-days" to complete the activity. The EQUALOC subroutine of the MAFESS program uses the Bennett algorithm to assign the equipment to the activity network, "crashing" the network where necessary to schedule equipment constrained activities. The final output report assigns each type of equipment on a day by day basis to each work activity requiring this equipment. Figures 5.6 and 5.7[25] shows the flow chart of the EQUALOC subroutine.

The state of the art, in relation to this problem, is the special research project of LCDR Robert Setzekorn. Setzekorn saw the design of an improved road in the AOA as a task ideally suited to microcomputer processing and solution. To ensure that the memory storage capacity of the microcomputer chosen to implement this program was not exceeded, Setzekorn divided his program into a software package with five functional stages. Those stages are Horizontal Alignment, Superelevation, Vertical Alignment, Soils, and Cross Section. Figures 5.8 and 5.9[1] show the flow chart of the program and the relationships between the five functional stages.

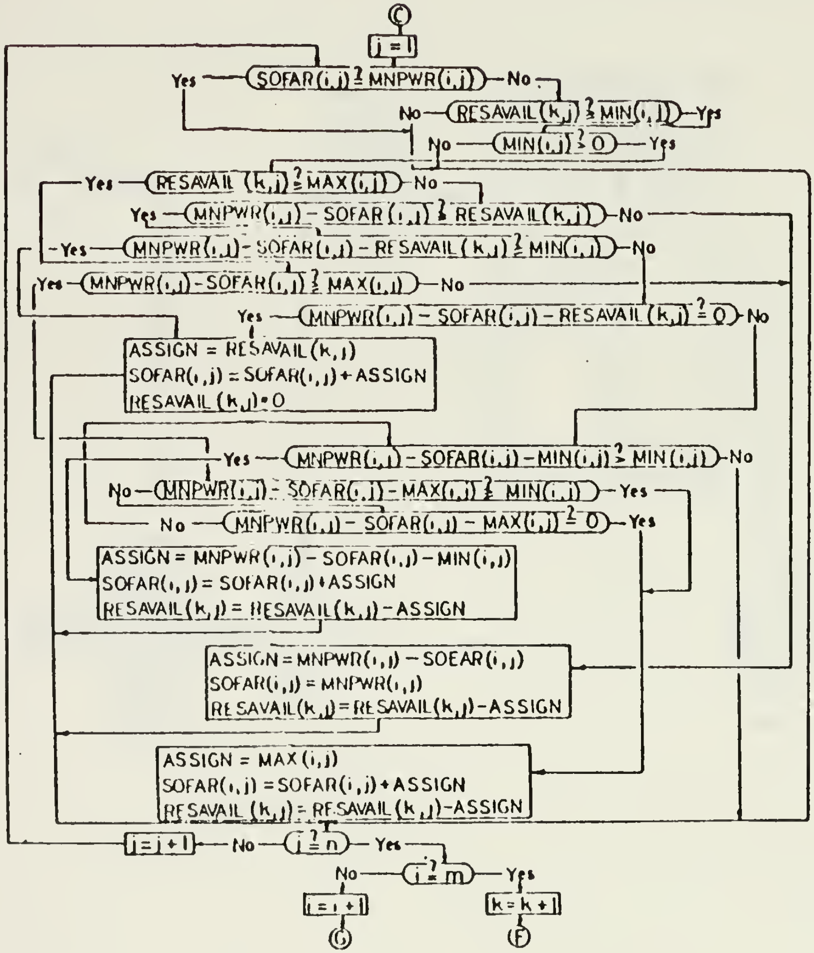
The overall program was designed for interactive input. The user is required to provide a rough layout of the road on a grid map. From this layout the user is asked to provide input information. Typical input requirements would be:

1. Number of curves



EQALOC Subroutine Flow Chart

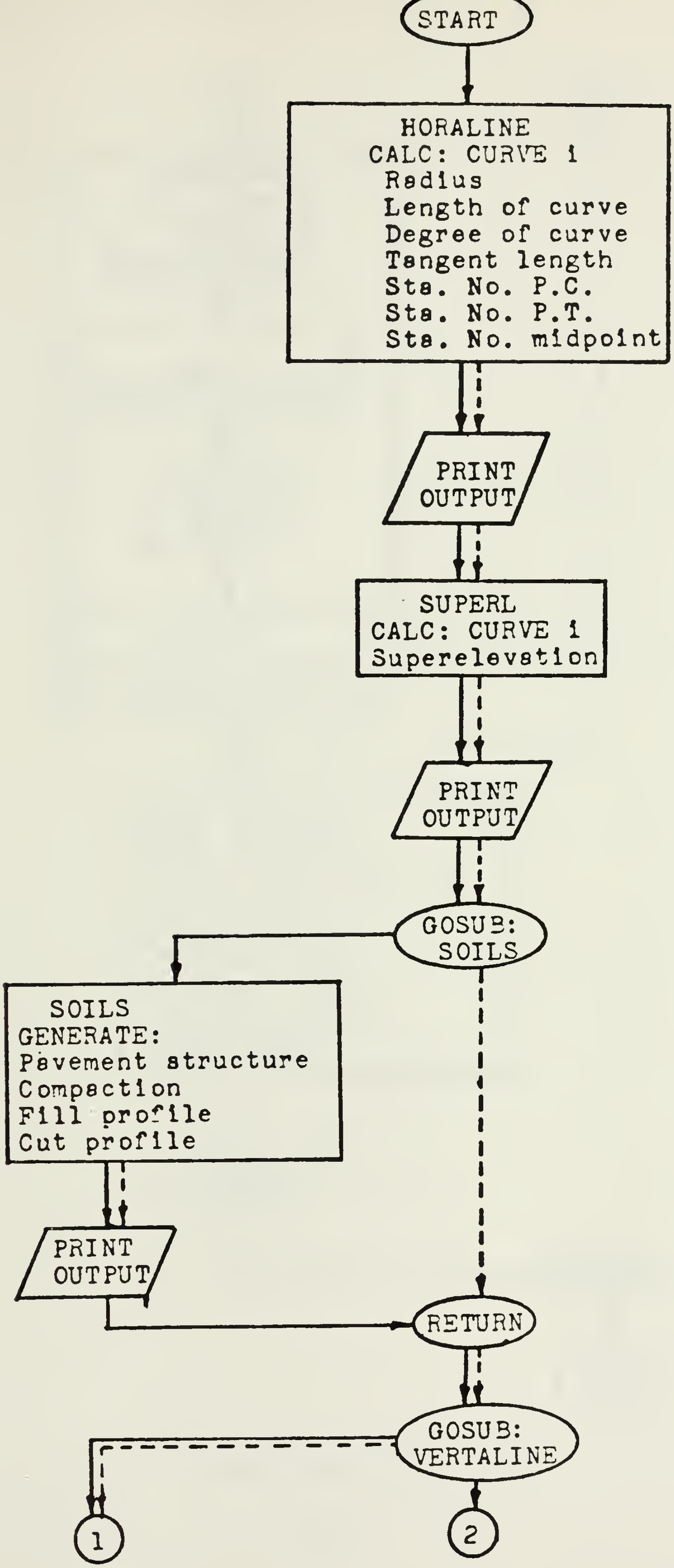
Figure 5.6


C
j = 1
Yes
SOFAR(i,j) ? MNPWR(i,j)
No
No
RESAVAIL(k,j) ? MIN(i,j)
Yes
No
MIN(i,j) ? 0
Yes
Yes
RESAVAIL (k,j) ? MAX(i,j)
No
Yes
MNPWR(i,j) - SOFAR(i,j) ? RESAVAIL(k,j)
No
Yes
MNPWR(i,j) - SOFAR(i,j) - RESAVAIL(k,j) ? MIN(i,j)
No
Yes
MNPWR(i,j) - SOFAR(i,j) ? MAX(i,j)
No
Yes
MNPWR(i,j) - SOFAR(i,j) - RESAVAIL(k,j) ? 0
No
ASSIGN = RESAVAIL(k,j)
SOFAR(i,j) = SOFAR(i,j) + ASSIGN
RESAVAIL(k,j) = 0
Yes
MNPWR(i,j) - SOFAR(i,j) - MIN(i,j) ? MIN(i,j)
No
No
MNPWR(i,j) - SOFAR(i,j) - MAX(i,j) ? MIN(i,j)
Yes
No
MNPWR(i,j) - SOFAR(i,j) - MAX(i,j) ? 0
Yes
ASSIGN = MNPWR(i,j) - SOFAR(i,j) - MIN(i,j)
SOFAR(i,j) = SOFAR(i,j) + ASSIGN
RESAVAIL(k,j) = RESAVAIL(k,j) - ASSIGN
ASSIGN = MNPWR(i,j) - SOEAR(i,j)
SOFAR(i,j) = MNPWR(i,j)
RESAVAIL(k,j) = RESAVAIL(k,j) - ASSIGN
ASSIGN = MAX(i,j)
SOFAR(i,j) = SOFAR(i,j) + ASSIGN
RESAVAIL (k,j) = RESAVAIL (k,j) - ASSIGN
j = j + 1
No
j ? n
Yes
No
i ? m
Yes
i = i + 1
k = k + 1
G
F

ASSIGN = resource assignment;
i = activity number = 1,2, ... m;
IBEGIN (i) = begin event number for activity i;
IDUM (i) = dummy designator for activity i {0: Real activity, 1: Dummy activity;
INUM = counter used with ISAME to determine whether all activities entering event NUM have been completed;
IRES = counter used to determine whether all of an activity's required resources have been assigned;
ISAME = counter used with INUM to determine whether all activities entering event NUM have been completed;
ISTAT (i) = status designator for activity i {0: Not yet eligible for scheduling, 1: Eligible for scheduling, 2: Resource scheduling underway but not completed, 3: Resource scheduling completed;
ISTAT 3 = counter used to determine whether all activities have been scheduled;
j = resource number = 1,2, ... n;
JEND (i) = end event number for activity i;
k = day number = 1,2, ... 400;
m = number of activities;
MAXEVENT = maximum event number;
MAX (i,j) = maximum amount of resource j that can be assigned to activity i;
MIN (i,j) = minimum amount of resource j that can be assigned to activity i, if any is assigned;
MNPWR (i,j) = total requirement of resource j for activity i;
n = number of resources considered;
NUM = counter on begin and end event numbers, used to determine whether the entire network has been searched;
RESAVAIL (k,j) = amount of resource j available on day k; and
SOFAR (i,j) = amount of resource j that has been assigned to activity i at any given time.

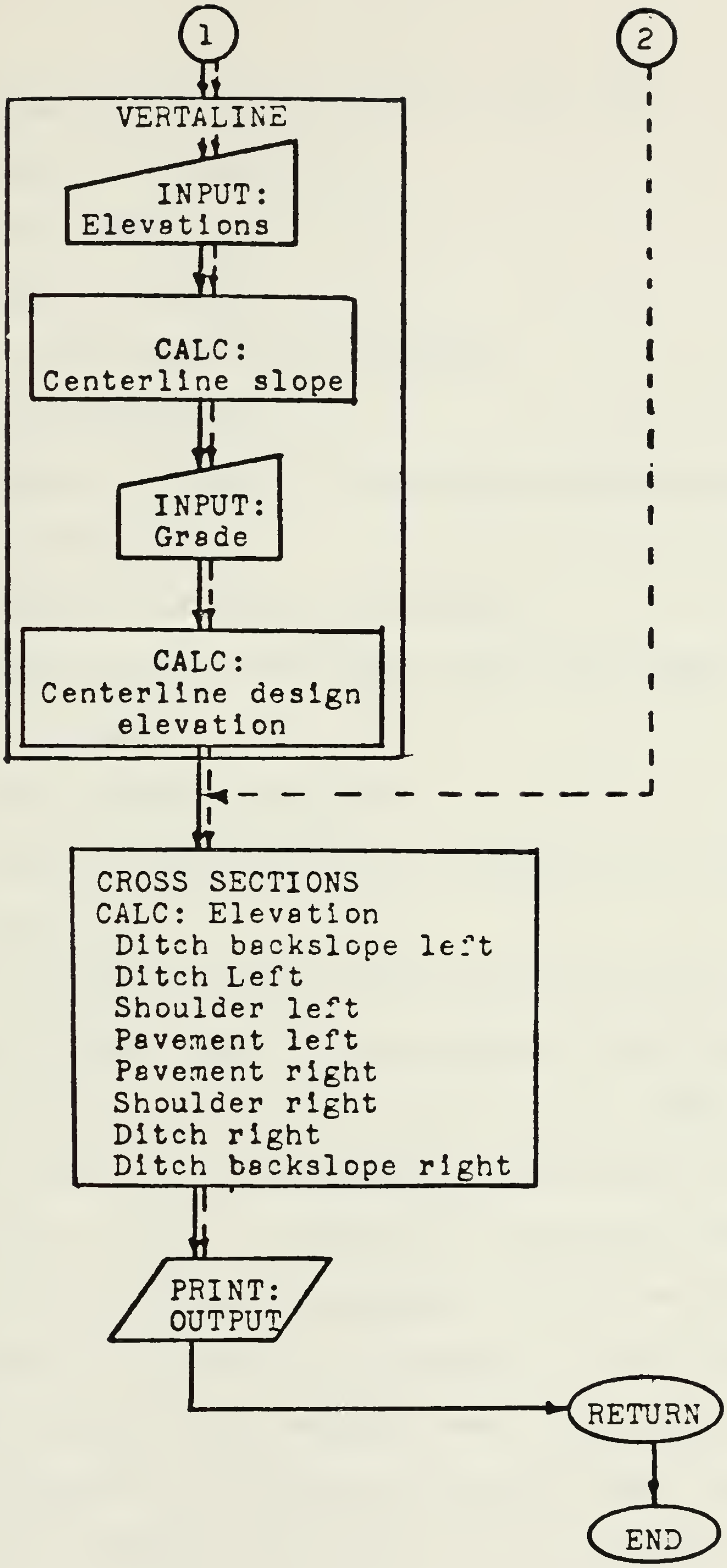
EQALOC Subroutine Flow Chart

Figure 5.7



Road Design Flow Chart

Figure 5.8



Road Design Flow Chart

Figure 5.9

2. Centerline intersection of each curve
3. Angle of intersection
4. Chord length
5. Design Velocity
6. In-place density of subgrade
7. CBR of subgrade
8. Numbers and types of base and subbase materials and CBR of each
9. Number of stations in section
10. Elevations of centerline, left and right side of pavement
11. Grade between stations
12. Number of stations to be included in a vertical curve.

The Horizontal Alignment and Superelevation subroutines develop station data based on the length of the curve. All other subroutines provide calculation based on 100 foot stations. However the user is not necessarily constrained by this interval. The output data is both in graphical and tabular form. The pavement and base design is graphical, where the distance between layers on the cross section is indicative of its relative thickness. The horizontal and vertical curve data, and the superelevation information is given in tabular form. Both Setzekorn's program and the program developed in one's research assume the user is an engineer with highway/surveying background. The need for this background will be discussed in the next section.

CHAPTER VI

PROGRAM DESIGN

The design methods used in the development of this program are, for the most part, procedures developed in Army technical manuals.[26, 27, 28] The program was developed in eight functional stages; the first five of which were derived from the special research of LCDR Robert Setzekorn. These eight functional stages are listed below:

1. Horizontal Alignment
2. Superelevation
3. Soils
4. Vertical Alignment
5. Cross Section
6. Intersection Points
7. Cross Sectional Area
8. Mass Balance

The last three stages and the Vertical Alignment stage rely to some degree on the design procedures expressed by references (29) and (30). These design procedures will be fully explained later in this chapter. The overall program, FIRD (Fortran Interactive Road Design) was developed as a series of subroutines which handle the eight functional stages.

As the program was written for interactive input, care must be taken to insure the proper format of input data. To this purpose a user's manual for the program was prepared, and is listed as Appendix C. Similarly, a detailed flow chart is listed in Appendix D. It may be useful to refer to these

appendices during the below discussion of the design procedures.

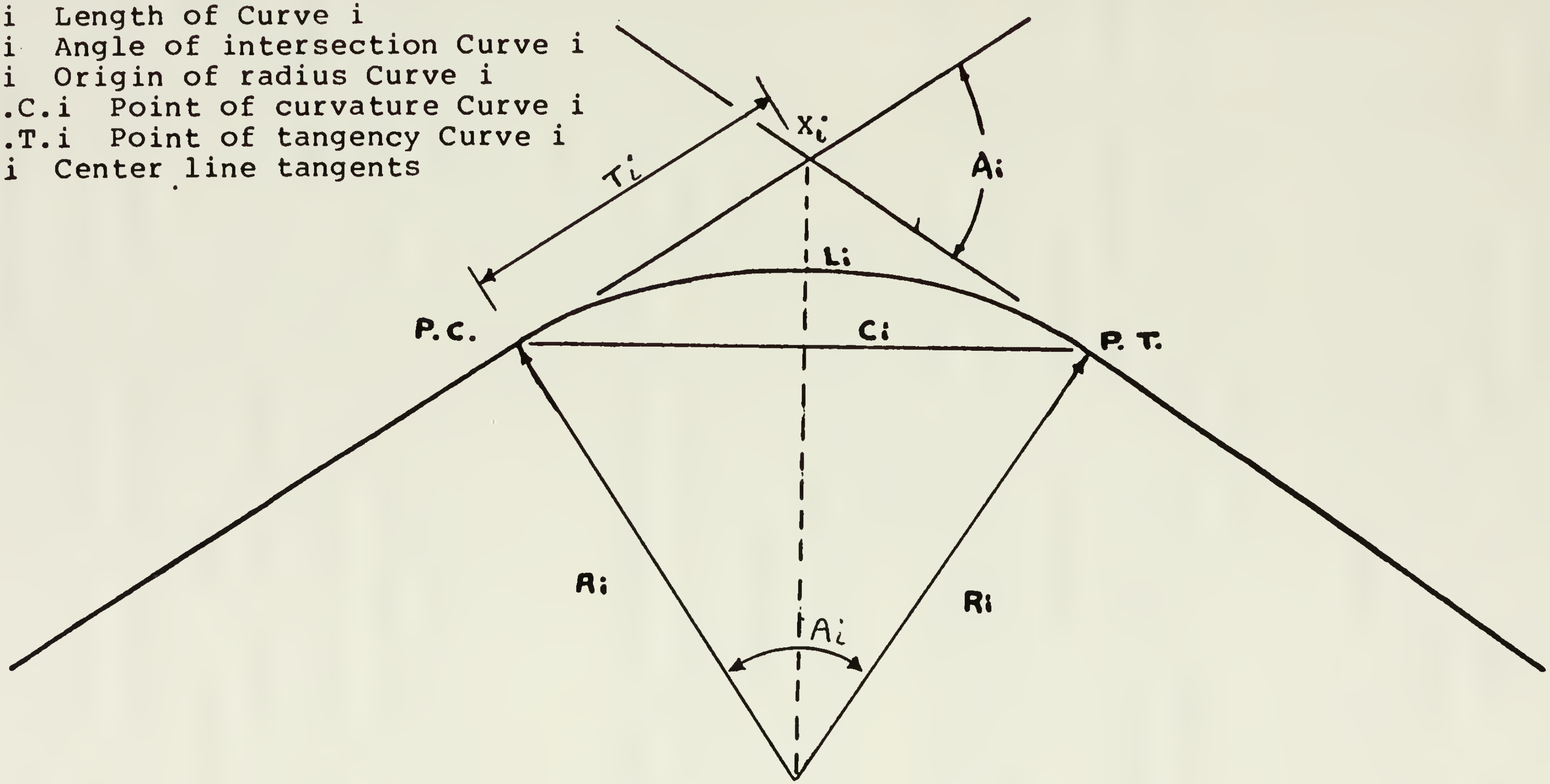
Horizontal Alignment

The first design item to be addressed in any road design is the horizontal alignment. Here the engineer selects the alignment of the road centerline. Usually this is accomplished by studying contour or terrain maps of the area in question. The engineer attempts to select that route that most expeditiously reaches the desired location, while minimizing cuts and fills and avoiding natural obstacles. Layout is usually restricted to a series of straight line segments and curves. This alignment is recorded by stations, where straight line segments are assigned full station numbers at 100 foot intervals. Rarely will the beginning point of a curve (PC) lie at a full station.

The horizontal curve programming of FIRD was designed to handle only simple curves. Complex curves can be approximated however by combining a series of adjoining simple curves. An example of a simple curve and curve component definitions are given by Figure 6.1.[1] The program starts interactive input by requesting the number of horizontal curves in the road section being designed. Up to twenty horizontal curves can be designed per road section. If no curves are to be designed in the road section, the user types in 0. In this case the program bypasses the Horizontal Alignment and Superelevation sections and proceeds directly to the Soils section.

If horizontal curve data is desired, the computer requests the station number of the point of intersection of the tangent lines. This point is shown by point X on Figure 6.1. Next

Ri	Radius of curvature-Curve i
Ci	Chord length of Curve i
Li	Length of Curve i
Ai	Angle of intersection Curve i
Oi	Origin of radius Curve i
P.C.i	Point of curvature Curve i
P.T.i	Point of tangency Curve i
Ti	Center line tangents



HORIZONTAL CURVE GEOMETRY

Figure 6.1[1]

the angle of intersection between the two tangent lines (A_i), and the curve chord length (C_i) are input. Once these have been input the program proceeds to calculate the curve data.

The first calculation to be made is the Radius of Curvature (R):

$$R_i = C_i/(2 \times \sin (A_i/2)) \qquad 6.2$$

Though the angle of intersection A_i is inputted in degrees, the program internally converts this angle to radians prior to the calculation of horizontal curve data.

The length of the curve is calculated next. This is defined as the arc length of the inscribed circle:

$$L = A_i \times R_i \times 3.14/180 \qquad 6.3$$

The calculation of the degree of curvature is next considered. The program limits this value to be less than ten for safety reasons. The degree of curvature (D_i) is defined as the angle of intersection between the radii of an arc whose chord length is 100 feet.

$$D_i = 5729.28/R_i \qquad 6.4$$

If the degree of curvature is determined to be more than ten, the program warns the user and returns him to the point in the program which requests the station number intersection of the tangent lines (X_i). The user may decrease the degree of curvature value by decreasing the angle of intersection, increasing the chord length, or completely realigning the curve.

If the degree of curvature is found to be less than ten, the program proceeds to calculate the tangent distance (T_i) from the point of intersection to point of curvature (P.C) and

point of tangency (P.T.).

$$T_i = R_i \tan (A_i/2) \qquad 6.5$$

From this calculation the station numbers of the P.C., P.T., and midpoint of the arc length (M_i) are determined:

$$P.C. = X_i - T_i \qquad 6.6$$

$$M_i = P.C. + L/2 \qquad 6.7$$

$$P.T. = P.C. + L \qquad 6.8$$

Finally, the program outputs all the horizontal curve data in tabular form. This output consists of the following:

1. Station Number of the Midpoint of the Curve
2. Radius of Curvature
3. Length of Curve
4. Degree of Curvature
5. Tangent Length
6. Station Number of the P.C.
7. Station Number of the P.T.

Though the horizontal curve design stage has been completed, a redesign of this curve may be necessitated by the saftey features of the superelevation design stage. This will be discussed later in this chapter.

Superelevation

Superelevation of a road section is used by the engineer to prevent slippage of vehicle tires while a vehicle is moving along a curve. It is a safety feature most commonly used when the degree of curvature (D) and designed road speed (V) are high.

In this program, the user has the option of four design road speeds: 30, 40, 50, or 60 miles per hour. If a design road speed other than these are selected, the user is instructed to reselect.

If a valid velocity has been selected, the program calculates a superelevation ratio, using the equation listed below:

$$E = (V^2/15 \times R) - F \qquad 6.9$$

In this equation, V is the design speed (in miles per hour), R is the radius of curvature (in feet), and F is a side friction factor. The side friction factor is a function of the design speed and is stored within the program as follows:

V (mph)	F
30	0.16
40	0.15
50	0.14
60	0.13

The program automatically choses that side friction factor that corresponds with the input design speed.

If the calculated superelevation is zero or less, the program assumes no superelevation on that road section. If the superelevation ratio is between zero and 0.08 foot per foot, the program accepts this value and stores it for output. If the superelevation ratio is between 0.08 and 0.10 the program asks the user to input whether snow is prevalent in the area. If snow is not a factor, the program accepts the superelevation value and continues on. If snow is prevalent, the program warns the user that the superelevation ratio is too high and returns the user to the beginning of the horizontal alignment stage for curve redesign. In any case, if the superelevation ratio exceeds 0.10 the program will automatically call for a horizontal curve redesign.

As reinput of all curve data is necessary in the event of excessive superelevation values, it is important for the engineer to carefully evaluate this condition before initializing the curve data. Sometimes a series of transition curves can be used to provide a gradual cross section change.

If the calculated superelevation ratio is acceptable, the program proceeds to output all the horizontal curve and superelevation data in tabular form. This output consists of the following:

1. Station Number of the Midpoint of the Curve
2. Radius of Curvature
3. Length of Curve
4. Superelevation
5. Tangent Length
6. Station Number of the P.C.
7. Station Number of the P.T.

Some of this data is stored for later use in the Cross Section Design stage of the program.

Soil Design

The next design stage, Soils, designs the road section structurally, such that it is able to accept the designed loads. First, however, it will be necessary for the engineer to determine what amount and types of traffic will utilize the road. This entails an estimate of the Average Daily Traffic (ADT) and the percentage of that ADT comprised of vehicles heavier than passenger autos and light pickup trucks. By Figure 6.10, the engineer is able to classify the road by the ADT and the percentage of heavy vehicles.

For example, suppose the ADT is expected to be 3300 vehicles per day and the percentage of heavy vehicles is estimated at

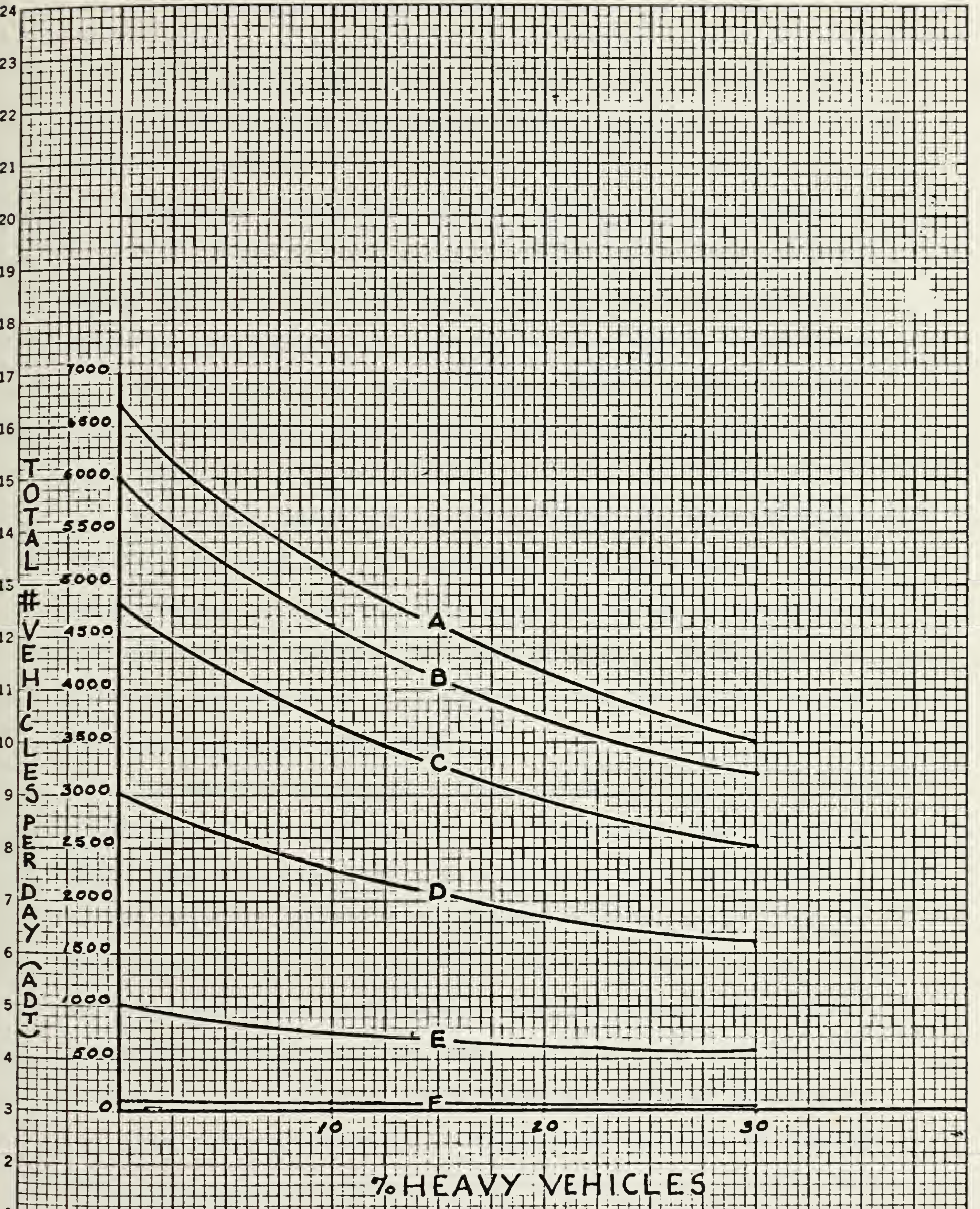


FIGURE 6.10 ROAD CLASSIFICATION

22%. By plotting this point on Figure 6.10, it may be seen that the curve above that point is B. Therefore a class B road would be required.

Similarly Figure 6.11 allows the engineer to convert the road classification into a design index. By taking the road classification B and a twenty-two percent of heavy vehicle estimate into Figure 6.11, it can be seen that a design index of 5 would be required. Both these design indices are based on a heavy vehicle classification of 18,000-pound equivalent axle loads.

The design index will be used by the program to design the flexible pavement and the subsurface base structures. As with manual design procedures, this is accomplished by determining the total road structure above the subgrade. From this calculation the design of the pavement, from the surface to the subbase, can be accomplished.

The user first inputs a road design index and an estimate of the actual in-place density of the subgrade into the program. The subgrade density must be input as a percentage of the modified proctor. The program then requests input on the number of soil layers to be used in the substructure (base, subbase, and select materials). Usually no more than three different materials are necessary. The program has the capability of handling up to seven different materials, however.

The surface thickness is established by input of the CBR (California Bearing Ratio) of the selected base course. The program accomplishes this by selecting the pavement thickness

ROAD CLASSIFICATION	% HEAVY VEHICLES			
	0	10	20	30
A	3	4	5	6
B	3	4	5	6
C	3	4	4	6
D	2	3	4	5
E	1	2	3	4
F	1	1	2	3

Design Index

Figure 6.11[1]

required at that base CBR for the road classification chosen. The below table of data is stored in the program for this purpose:

	A	B	C	D	E	F
CBR $\geq$ 100	3.5	3	2.5	2	1.5	1
$\geq$ 80	4	3.5	3	2.5	2	1.5
$\geq$ 50	5	4.5	4	3.5	3	2.5

After the program selects the pavement thickness, the program evaluates the thickness of the material above the subbase. This depends upon whether the lower material has a CBR greater than or less than six, and the design index. If the CBR is less than 6, the design index (D1) is incorporated by the following equations:

$$\text{Thickness} = \text{Integer}\ (1/A1 + (B1 \times CBR)) + 0.5 \tag{6.12}$$

$$\text{where:}\quad A1 = 1/(33.4189 + 6.9253 \times D1) \tag{6.13}$$

$$B1 = 1/(66.5698 + 14.6764 \times D1) \tag{6.14}$$

If the subgrade CBR turns out to be greater than 6, another set of equations are applied:

$$\text{Thickness} = \text{Integer}\ (1/(A + (B \times CBR)) + 0.5 \tag{6.15}$$

$$\text{where:}\quad A = 1/(26.7561 + 4.90148 \times D1) \tag{6.16}$$

$$B = 1/(73.9301 + 16.9388 \times D1) \tag{6.17}$$

Once the program has calculated the thickness of the surface and base course, it outputs that information and is ready to continue design. However, if the surface thickness required is only one inch or less with a base CBR of 80 to 100 the pro-

gram will recommend multiple bituminous surface treatment. Similarly if the required surface thickness is only 0.5 inches and the base CBR is 100, a bituminous surface is recommended. The overall thickness of the surface and base course is restricted to be a minimum of six inches, with a base course thickness of at least four inches.

The thickness of the subbase and select materials is considered next. The total thickness of the subbase material is equal to the difference between the total pavement thickness and the total surface / base course thickness. From this quantity, the minimum thickness of each of the subbase/select materials chosen is subtracted until the subgrade is reached. For instance if the total pavement thickness is fourteen inches and the surface/base course material total thickness is seven inches, the total subbase material thickness would be 14-7 = 7 inches.

Upon completion of the pavement substructure design, the program outputs a road cross section indicating asphalt pavement, base, subbase, and select material with their associated depths in inches and soil CBR. Then the compaction requirements of the materials are considered.

The program first evaluates each of the selected materials with regard to their CBR values. If the CBR of any of these materials is less than twenty and the subgrade is noncohesive, the compaction of that material is set at 95%. If the CBR of that material is less than twenty and the subgrade is cohesive, compaction is set at 90%. If the CBR of the material is above twenty, compaction is established at 100%. This data is then

output to the user is cross section format with cumulative depth, percent compaction, and the CBR of the material indicated. The subgrade is temporarily assigned a compaction of 95% for noncohesive materials or 90% compaction for cohesive materials.

The program next evaluates the compaction requirements of the fill sections. The thickness of the required fill section for a pavement with a cohesive subgrade is determined by:

$$\text{Thickness} = A1 + B1 \times I \qquad 6.18$$

where: $A1 = 70.7932 + 14.3841 \times D1$ 6.19
$B1 = -0.677999 - 0.136691 \times D1$ 6.20

Similarly, the thickness of the required fill section for a pavement with a noncohesive subgrade is determined by:

$$\text{Thickness} = A2 + B2 \times I \qquad 6.21$$

where: $A2 = 119.487 + 25.3872 \times D1$ 6.22
$B2 = -1.13 = 0.240128 \times D1$ 6.23

The variable I in equation 6.18 and 6.21 is a compaction rate. This rate is incremented from 100 to 80 percent in five percent intervals.

If the compaction computed for the fill exceeds eighty percent, or the design thickness of the pavement structure equals the minimum thickness calculated for eighty percent subgrade compaction; a fill utilizing the subgrade material is specified. If the fill compaction is less than eighty percent, the program adds four inches of eighty percent compact subgrade material to the pavement substructure, with the re-

mainder of the fill to be subgrade material at the compaction calculated for the fill. If the compaction of the last select material exceeds the subgrade compaction by more than ten percent, the program has the subgrade scarified to six inches and recompacted, increasing the subgrade material compaction by five percent.

The final section of the soils design stage is the compaction requirements for cut sections. As with the fill soil design, the program compares the thickness required above the subgrade with the designed pavement substructure at varying compactive efforts. These compactions start at one hundred percent and decrease through eighty percent at five percent increments. If at some point, the required thickness is greater than the substructure thickness, the program requires the subgrade to be removed. This subgrade is then replaced at the compaction specified for that minimum thickness and to a depth such that the minimum thickness is achieved. This then becomes the new design thickness and the comparison is repeated. When the in-place density equals or exceeds the specified compaction or the compaction of the replaced material equals eighty percent, the replacement process is stopped. The new subgrade is then scarified to a depth of six inches and compacted to the density of the replaced material immediately above it.

The data for both the fill and cut section pavement structure is output in cross section format. All the cross section formated outputs within the soils subroutine are keyed such that approximately one-inch of material depth is spaced

four printer lines down.

Vertical Alignment

The vertical alignment design stage requires the greatest interactive effort with the user. The design procedures utilized were developed using the parabola method of reference (30). This differs from Setzekorn's program, which uses a modified version of the tangent offset method.

The first user input is the number of stations in the section. This is limited to a maximum of fifty. Next the user inputs the following information on each of the stations being designed:

1. Station Number
2. Is the Curve a P.C. Station? If so, does the horizontal curve skew off to the right hand side or the left hand side?
3. Station elevation on the left side (28.1 feet to the left of the centerline).
4. Station elevation at the centerline.
5. Station elevation on the right side (28.1 feet to the right of the centerline).

The second input parameter, dealing with horizontal curve configuration, is input to allow the program to proportion superelevation along the curve transition length. This will allow the road cross sections to be gradually modified from a crowned road section at the P.C. and P.T. points to full superelevation sections within the horizontal curve.

Overall, it is important for the user to ensure all P.C. and P.T. points, as well as all hundred-foot stations are inputted. Failure to input all station data will result in errant vertical alignment output.

After all station input has been received, the program outputs this data in tabular form as follows:

1. Station Number
2. Left Side Elevation
3. Centerline Elevation
4. Right Side Elevation
5. Slope

The slope output at any one station is the straight line percent slope between that station and the previous station. Negative slopes indicate a decrease in existing centerline grade. It is important that the user review these slopes before the input of final grade. Proper review of this data will minimize cut and fill requirements on the final road cross sections.

Next the program requests from the user the final grade percent slope (G_i) between each of the stations. After input for all stations has been received the program requests the final grade elevation of the first station. From this data the program internally generates a straight-line final grade profile for all stations by the following formula:

$$\text{Sta Elev}_{i+1} = ((\text{Sta Dist}_{i+1} - \text{Sta Dist}_i) \times G_i) + \text{Sta Elev}_i \qquad 6.24$$

The program then determines changes in final grade between consecutive stations and notifies the user of the need for a vertical curve at the inflection points (V). The user must then review the final grade input and select a length of vertical curve (L). Vertical curve alignment data is then generated using the following formulas:

$y = r/2\ x^2 + g_1\ x + \text{Elev BVC}$ 6.25

$r = g_2 - g_1/L$ 6.26

where: y = Station elevation at station i + 1
x = Distance between station i + 1 and station i (in hundred feet).
g_1 = Percent grade between the Beginning station of the Vertical Curve (BVC). and the grade inflection point (V).
g_2 = Percent grade between the Ending station of the Vertical Curve (EVC) and the grade inflection point (V).
L = Length of the vertical curve in hundred feet.

A sample of such a vertical curve and the parabolic elevation calculations is shown by Figure 6.27. These final grade station elevations are then stored for use on the cross section design stage.

The Cross section design stage computes a standard cross section for each of the stations. This standard cross section is depicted in Figure 6.28. The cross sectional distances of these station cross sections are permanent. However, the relative slope and elevation of the cross section reference points change as a road section passes through a horizontal curve.

On tangent sections, the program computes a crowned cross section through each of the reference points. These are defined as follows:

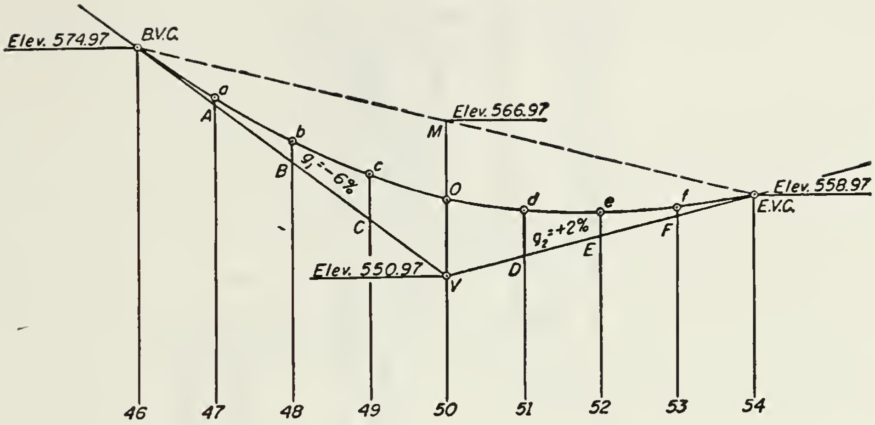
Pvmt Edge Elev = Centerline Elev - (11.5' x 0.042) 6.28

Shoulder Elev = Pvmt Edge Elev - (4.0' x 0.063) 6.29

Ditch Elev = Shoulder Elev - (4.5' x 0.333) 6.30

Backside Elev = Ditch Elev + (8.1' x 0.275) 6.31

As crowned road sections are symetrical, these equations apply



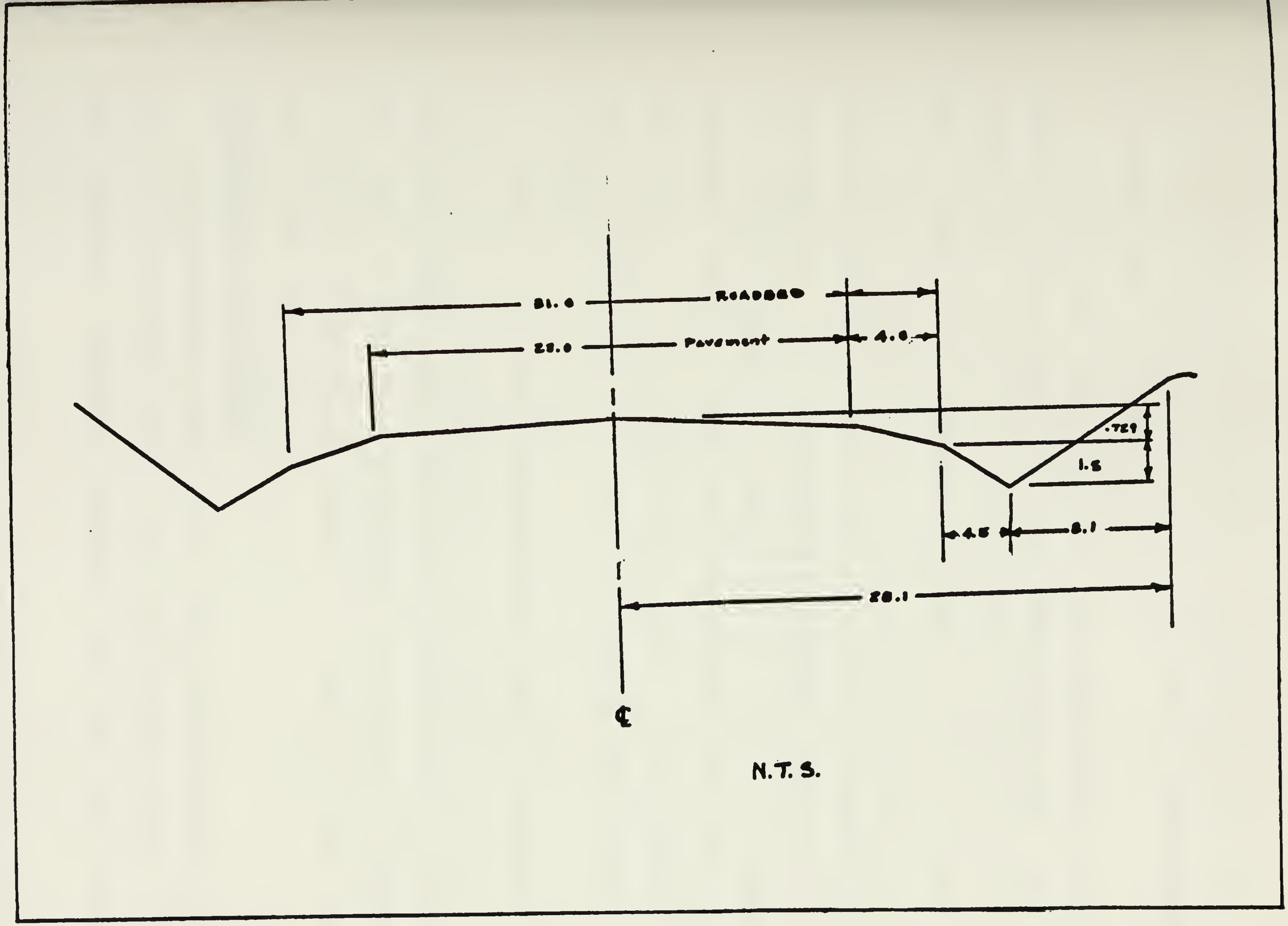
Typical Vertical Curve

Station	x	x^2	$\frac{r}{2}x^2$	g_1x	Elev. B.V.C.	Elev. Curve
B.V.C. = 15	0	0	0	0	882.35	882.35
16	1	1	− 0.33	+ 1.25	882.35	883.27
17	2	4	− 1.33	+ 2.50	882.35	883.52
18	3	9	− 3.00	+ 3.75	882.35	883.10
19	4	16	− 5.33	+ 5.00	882.35	882.02
20	5	25	− 8.33	+ 6.25	882.35	880.27
E.V.C. = 21	6	36	− 12.00	+ 7.50	882.35	877.85

Parabolic Elevation Calculations

Vertical Curve

Figure 6.27[30]



Standard Cross Section

Figure 6.28[1]

to both sides of the road in cut. If the road is in a fill section, the standard cross section stops at the shoulder and is sloped down to the fill toe.

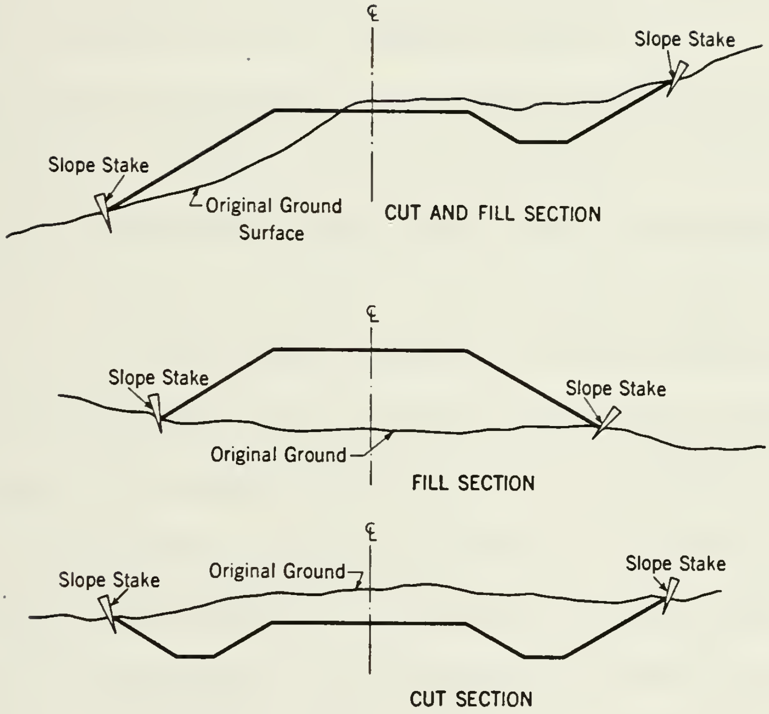
At horizontal curve sections, the program applies the superelevation ratios developed in the second design stage. The program first calculates a superelevation transition ratio. This is defined as a ratio between the P.C. or P.T. of the curve and the curve midpoint. In this way superelevation is gradually applied until full superelevation is achieved at the curve midpoint. Then superelevation gradually tapers off as the distance from the curve midpoint to the point of tangency increases. Finally, at the point of tangency, the cross section returns to the standard cross section. If no superelevation is required in the curve, the standard cross section is applied.

Output for the cross section design stage is produced in tabular form. The program outputs the backside, ditchline, shoulder, pavement edge, and centerline elevations at each station. Due to paper size limitations, the program is formatted to output this data in two sections: as elevations left and right of the centerline.

Intersection Point Design

The intersection point design stage was developed to determine the catch points between the existing grade and the roadbed sideslopes. These are designed as the slope stake points on Figure 6.32.

User input consists of a slope grade for every station



Intersection Points

Figure 6.32[29]

on both the right and left side of the standard cross section. As noted by Figure 6.32 this slope grade starts at the shoulder edge and slopes down to the slope toe on fill sections, and starts at the backside and slopes upward on cut section. The user inputs an integer which indicates to the program a slope ratio. For instance, a slope grade of four indicates the slope is one foot vertical to four foot horizontal (1:4). From this ratio, the program is able to calculate the intersection point between the design section and the existing grade.

The program determines each slope intersection point by an approximation method. First the program compares the existing and design shoulder edge elevations to determine whether the section is in cut or fill. The program then calculates the slope of the existing ground by interpolating between the existing ground centerline and left/right side elevations. If the design slope grade is found to be parallel with the existing slope grade, an error message is given and the user is instructed to select another design slope grade. If the slopes are not parallel, the program increments the slopes out, one horizontal foot at a time, until the elevations of the slopes either meet or cross one another. An error of less than one square foot per cross section is expected using this method.

Program output consists of the station number, grade elevation, and horizontal distance from the centerline; for both the right and left hand side slopes at each station. The data is presented in tabular form.

The cross sectional area design stage was developed to determine the cross sectional area of the cut or fill at each station. The design procedure utilized is known as the criss-cross method. This method treats each station cross section as a traverse. Each point of inflection on that traverse is given X and Y coordinates in relation to a reference point on the cross section. For the purpose of this program the left hand side intersection point was designated as the origin point. The program computes the cross-sectional area by use of the following equation:

$$\text{Double Area} = \sum_{i=1}^{n} Y_i(X_{i+1} - X_{i-1}) \qquad 6.33$$

where i equals the number of inflection points on the traverse.

An example of this calculation is given by Figure 6.34.

The calculation of the volume and cumulative volume at each station is also accomplished in the cross sectional area subroutine. The volume calculation utilizes the average end area method. According to this formula, the volume, in cubic yards, between two cross sections having areas A_0 and A_1 is:

$$V = \tfrac{1}{2}(A_0 + A_1)L/27 \qquad 6.35$$

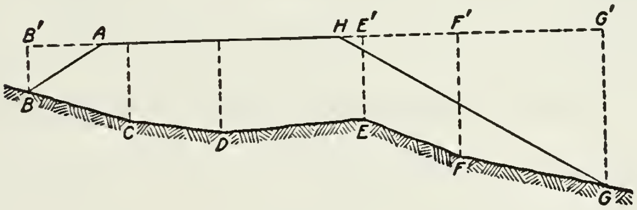
where: L is the distance between stations

First the program designates each cross section area as negative or positive, depending upon whether the section is a cut or fill respectively. The program then calculates the volume between each station using the average end area formula. Finally, the program sums all the volumes on a station by station basis, to get the cumulative volume between each station. The cumula-

A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
$\frac{F\ 0.0}{-12.0}$	$\frac{F\ 5.2}{-19.8}$	$\frac{F\ 6.8}{-10.0}$	$\frac{F\ 7.2}{0}$	$\frac{F\ 6.1}{+15.0}$	$\frac{F\ 7.4}{+20.0}$	$\frac{F\ 9.6}{+26.4}$	$\frac{F\ 0.0}{+12.0}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

$$\begin{array}{rl}
Y_n\,(X_{n+1} - X_{n-1}) & = \text{Double area} \\
0.0\,(-19.8 - 12.0) & = \ \ 0.0 \\
5.2\,(-10.0 + 12.0) & = +\ 10.4 \\
6.8\,(0.0 + 19.8) & = +\ 134.6 \\
7.2\,(+15.0 + 10.0) & = +\ 180.0 \\
6.1\,(+20.0 - 0.0) & = +\ 122.0 \\
7.4\,(+26.4 - 15.0) & = +\ 84.4 \\
9.6\,(+12.0 - 20.0) & = -\ 76.8 \\
0.0\,(-12.0 - 26.4) & = +\ \underline{0.0} \\
 & \ 2\overline{)454.6} \\
\text{Area} = & \ \ 227.3\ \text{sq ft}
\end{array}$$

Typical Criss-Cross Method
Cross Sectional Area Calculation



Cross Section in Question

Cross Sectional Area

Figure 6.34[30]

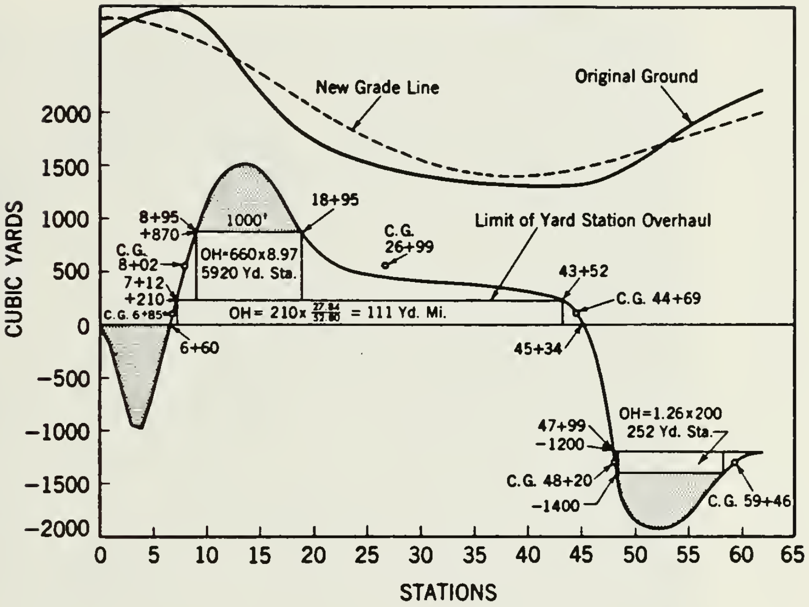
tive volumes will be used later in the program to plot a mass balance diagram.

The output from the cross section design stage consists of the station number and cross sectional area (in square feet) at each station, and the volume and cumulative volume (in cubic yards) between each station. The data is presented in tabular form.

Mass Balance Development

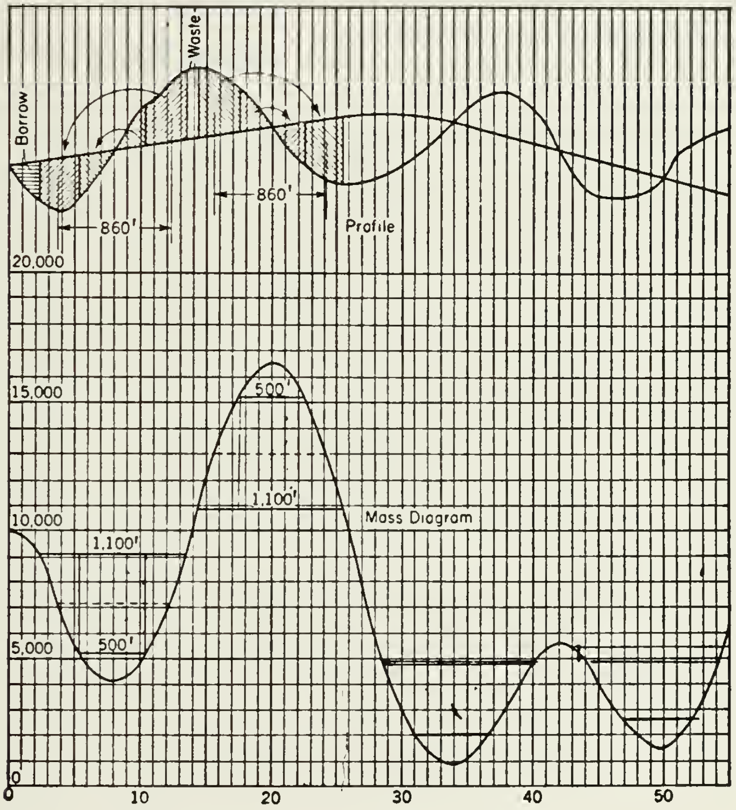
The final design stage, mass balance, determines the amount and location of the maximum and minimum cumulative volumes. Further it plots the cumulative volume versus the station numbers on the Versatec plotter. This plot is known as a mass diagram. An example of such a plot is given by Figure 6.36.

The mass diagram is utilized by construction managers to determine the amount of borrow and waste generated by the earthwork design. As shown by Figure 6.36, a typical road design contains both cut and fill sections. Often it is possible to use a portion of the cut section earthwork volume on the fill sections. This is shown on Figure 6.37. This eliminates the need to borrow more fill material than is necessary on a job. Further the construction manager can determine what amount of excess cut, if any, will have to be wasted (carried off the job). In civilian practice, the mass diagram is sometimes even more useful than a material distribution device. Some construction contracts limit the distance the contractor is expected to haul material taken from excavations to form embankments. This distance is known as the limit of free haul. Any distance



Mass Diagram

Figure 6.36[30]



Mass Diagram Showing Borrow
And Waste Volumes

Figure 6.37[29]

in excess of this is known as overhaul, and is associated with a recompensable expense.

In this program, the maximum and minimum cumulative volumes are determined by means of a sort routine. This output data is presented in written form on the printer. This is the last data output by the line printer. The Versatec plotter plots the mass diagram output. Cross marks indicate the amount of cumulative volume accrued at each station. After output of this data, the program ends.

CHAPTER VII

CONCLUSIONS

The need for computer aided designs in the field of combat engineering is both present and pervasive in the Armed Forces. Current research in this area quite correctly centers around the use of small, mobile computers; even if the state of the art in the computer manufacturing world has not advanced sufficiently to produce a model which can endure the rugged field conditions. Many of the CAD's developed by the Navy and at the Georgia Institute of Technology have dealt with the construction problems facing the military engineer in an Amphibious Objective Area. Program FIRD can now be added to that list.

Though program FIRD was prepared on the Cyber 70 system at the Georgia Institute of Technology, an effort was made to develop the program as a series of subroutines. Each of these subroutines are fairly inclusive, with both the input and output of each subroutine developing a design stage in its entirety. No single subroutine is excessively long, or beyond the storage capacities of most microprocessors. Most importantly, the design methods utilized by the program are not complex. Only simple curves are designed in the Horizontal Alignment subroutine, the CBR method is the most common procedure in pavement design, and the criss-cross method of determining the cross-sectional area of a traverse is the most flexible method available. These, among other factors,

lend themselves to the concept of translating program FIRD to a microprocessor for the benefit of a combat engineer. The only real probelms facing such an endeavor are associated with the translation of the present fortran IV program coding to the actual microprocessor language. This is especially noteworthy in the Mass Balance subroutine, where the Cyber system requires highly specialized "calls" to activate the Versatec plotter.

The overall program, though crude, is both servicable and safe. A listing of the program is given by Appendix E. There are some limitations to this program. The most important of these pertain to the friendliness of the system. There are many input parameters to be entered in a road design (especially in the Vertical Alignment design stage). It would be advisable to redesign some of the input formating such that errant entries can be easily corrected without jepardizing the entire program run. In addition, if the program is to be maintained in its entirety, a "menu", leading the user to each of the design stages should be added. Finally, some provision for the input of data by tape should be included. It was felt that these items might better be addressed by the needs of the user.

Some of the individual subroutines have built-in design limitations. The superelevation subroutine pro-rates the superelevation along the entire length of the horizontal curve. The only time full superelevation is reached is at the midpoint of the curve. It may be necessary to pro-rate the superelevation upon a shorter transition length, in the case of a long hori-

zontal curve. The determination of the intersection points between the existing ground and design road section uses an approximation method. This can lead to an error of up to one square foot per road section. The implementation of a linear regression method would eliminate this error. The cross-sectional area calculation does not provide for the depth of the pavement. This leads to slightly higher areas of fill and slightly lower areas of cut than truly exists. This was overlooked in the program design stage of the development of this research.

Finally, the quality of the mass balance curve from the Versatec plotter is somewhat below average. Sample runs produced graphs somewhat off in the plotting of the station locations. It is thought that this is at least partly due to hardware problems in the plotter itself. The message below seems to confirm this assertion.

```
NEWS FOLLOWS...
LAST NEWS RUN ON     81/11/03. 10.00.53.

81/11/03. 19.09.40.
   DUE TO A HARDWARE PROBLEM, THE QUALITY OF
 VERSATEC PLOTS WILL BE BELOW AVERAGE. OCS
 HOPES TO CORRECT THIS PROBLEM BY NOON WEDNESDAY.

81/11/03. 16.16.35.
 THE CALCOMP PLOTTER IS DOWN DUE TO HARDWARE
FAILURE. THE CALCOMP SHOULD BE UP ON 81/11/04
BY 1800.
```

Due to time limitations, this matter was not investigated more fully. A sample run indicating this problem, as well as demonstrating the capabilities of the entire program, is provided by Appendix F.

There are many ways program FIRD can be enhanced. Plots of the vertical alignment and station cross sections may be required. It may be desirable (though certainly not easy) to output all the plots on a line printer. Even more practical to the combat engineer however, would be subroutines which determine operator and equipment requirements, as well as durations, based upon the cut and fill volumes. Perhaps some interface between program FIRD and the MAFESS program of Lt. D. Pruett might eventually be developed.

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APPENDIX A

Programs Developed by US Army Engineer School

1. BAILEY BRIDGE - This program computes the type of bridge and its installation time, given the gap width, bank elevations, soil conditions and required load class.

2. BRGCLASS - This program classifies wood and steel stringer spans up to 60 feet in length.

3. BRGDES - This program computes the size of wood or steel stringers for fixed span bridges.

4. CPM - This program analyzes critical path method networks.

5. CRUSH - This program computes the jaw and roll settings and screen dimensions for 75 TPH rockcrusher.

* 6. DEMO - This program computes charges and installation times for specific explosive applications.

7. DITCH - This program computes ditch sizes given soil condtions, flow and slope.

8. EXTWIRE - This program computes the power distribution requirements from generator sources.

9. FLEXIBLE PAVEMENT - This program computes pavement and subbase design to include CBR, compaction, and thickness.

10. H CURVE - This program computes horizontal curve data.

11. MASABT - This program computes mass concrete bridge abutments.

*12. MINFLD - This program computes the logistical and manpower requirements for breaching and clearing minefields.

*13. OBSTACLE - This program computes materials, troop effort, and equipment requirements for specified obstacles in a barrier plan.

14. QUARRY - This program computes blast patterns for rock quarries.

*Program with non-construction application.

15. RIVFUN - This program computes floating bridge and raft requirements.

16. STLSTR - This program computes steel beam stringer sizes for fixed span bridges.

17. VERTCURV - This program computes vertical curve elevations.

18. WOODSTR - This program computes wooden stringer sizes for timber trestle bridges.

APPENDIX B

Programs Developed by 20th Engineer Brigade

* 1. CHISQR - Computes the CHI square statistic for non-parametric testing of independence of two variables.

2. CONNAN - Tracks all construction projects in the brigade. Interacts with EQCOST and PROJCOST.

3. CROSSEC - Computes the cross-sectional area of a polygon by utilizing the distance from centerline and relative elevation of each point in the polygon.

4. CURVE - Provides a computer profile plot of topographic elevations and computes slopes between stations.

5. EARTH1 - Provides a graphical plot of the topographic lines and design grades with all slopes and elevations. Additionally, it provides a mass diagram.

6. EARTH 25 - Controls a system of programs to obtain topographic and grade profiles as well as earthwork estimates and mass diagrams using random horizontal distances.

7. EQCOST - Stores data on rental and depreciation costs.

8. EQSTAT - Computes daily equipment status of selected items of equipment. The report reflects the number on hand, number committed, number available, the deadline rate, and commitment rate based on number operational.

* 9. GSEARCH - Searches an obstacle list for obstacles within a specific area and produces a listing containing logistical information.

*10. LOGSHIP - Provides weight and dimensions on table of equipment items for rail, sea, and air deployment.

*11. LOGSTAT - Provides listings of table of equipment by line number sequence. Listings can be grouped by commodity code and the total items or a combined list of several units can be generated.

*Program with non-construction application.

12. LOGSTAT3 - Produces logistical status reports in the form required by Third Corps.

13. MANPOWER ANALYSIS - Records, categorizes and plots trends in daily manpower utilization.

*14. MINEFLD2 - Assists in the planning and operational aspects of standard pattern minefield installation.

*15. OBS - Computes logistical and manpower requirements for a Brigade Obstacle Plan.

16. PROJCOST - Records manhours and equipment hours to compute funded and unfunded project costs.

*17. RAFTOPN2 - Produces a complete time table given the rafting assets and equipment to be crossed.

*18. ROSTER - Updates, sorts and prints the Brigade's officer roster.

19. RUNWAY - Provides a graphical representation of landing and clear zones requirements for C-130 aircraft.

*20. STEVRS/STDEVGE - Calculates the mean and standard deviation of random sample and grouped frequency data respectively.

*21. SQTP - Prints an individual letter to each soldier to inform him of the SQT test which he is to take and prints a roster for each unit to inform the commander of all personnel in his unit that will be tested.

*Program with non-construction application.

APPENDIX C

USER'S MANUAL FOR PROGRAM FIRD

USER'S MANUAL

INTRODUCTION

This user's manual contains step-by-step procedures to operate program FIRD. As FIRD is an interactive program, the computer provides questions which you, the user, must answer. Many of these questions are technical decisions, usually handled by a highway engineer. Therefore the user may find it helpful to read Chapter VI - PROGRAM DESIGN, which delineates the engineering basis for these decisions, before inputting.

Program FIRD is currently loaded on the CYBER-70 system at the Georgia Institute of Technology. All procedures set forth in this manual (except log-on procedures) refer to the CYBER system. All the procedures in this manual have been numbered. In general, the steps indicating correct input are consecutively numbered (i.e., 1, 2, 3, etc.).
Steps indicating errant input, design comments, or program output are numbered and alphabetized (i.e., 1A, 1B, 1C, etc.).

Before using the program, read all of the instructions carefully and assemble your input data. Good luck.

FIRD PROGRAM PROCEDURES

STEP 1

After logging on the computer, address program FIRD with the below job control commands. If a program listing is required interchange L = 0 in the FTN command with R = 0.

```
 OLD,FIRD
/ATTACH,CALCOMP/UN=LIBRARY
/LIBRARY(CALCOMP)
LIBRARY(CALCOMP)
/FTN,I=FIRD,L=0,TS
    16.308 CP SECONDS COMPILATION TIME
/LGO.
```

STEP 2

The program will initialize with some comments and proceed to the HORIZONTAL ALIGNMENT design stage. The first input data is the number of curves to be designed in the road section. A maximum of twenty curves can be designed at one time. This is input as an integer in I2 format (i.e., _1 for one curve). If no curves are to be designed, type in 0 and the program will move on to Step 5 (Soils Design).

```
THIS PROGRAM IS A SERIES OF SUBROUTINES DESIGNED
TO ASSIST THE ENGINEER IN A MILITARY ROAD DESIGN.
THE OPERATION OF THE PROGRAM IS INTERACTIVE,
AND REQUIRES THE USE OF THE USERS MANUAL.

                                             HORIZONTAL ALIGNMENT


ENTER NO. OF CURVES THIS SECTION
?  1
```

STEP 3

The program will request input on the tangent intersection point of the curve, the angle of intersection, and the chord length. All three of these items are input as real numbers in F7.3 format (i.e., 133.333). From this data, the program calculates horizontal curve alignment and provides output in tabular form. From left to right this output reads as follows: curve midpoint station number, curve radius, length of curve, degree of curve, tangent length, beginning of curve (P.C.) station number, and end of curve (P.T.) station number.

```
ENTER STA NO OF TANGENT INTERSECTION OF CURVE  1
? 133.0

ENTER ANGLE OF INTERSECTION OF CURVE IN DEGREES
? 26.0

ENTER CHORD LENGTH IN FEET
? 600.0


       STA NO.    RAD      L OF C         D OF C        TAN LEN   PC STA    PT STA

       132.947   1333.62   605.181        9.46705       307.891   129.921   139.052
```

STEP 3A

As a safety feature, the program automatically checks on the degree of curvature (D). If the value of the degree of curvature exceeds 10.0, the program returns the user to Step 3 for curve redesign. This may be accomplished by decreasing the angle of intersection or increasing the chord length.

```
WARNING D TOO HIGH REESTABLISH PC, PT, ANDC



ENTER STA NO OF TANGENT INTERSECTION OF CURVE  1
? 133.0


ENTER ANGLE OF INTERSECTION OF CURVE IN DEGREES
? 26.0


ENTER CHORD LENGTH IN FEET
? 540.0


WARNING D TOO HIGH REESTABLISH PC, PT, ANDC



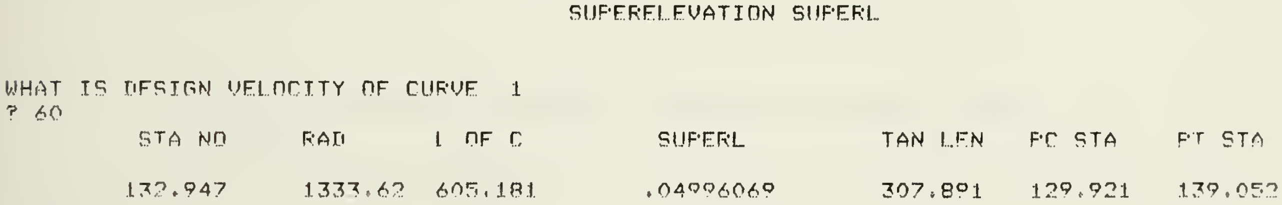
ENTER STA NO OF TANGENT INTERSECTION OF CURVE  1
? 133.0


ENTER ANGLE OF INTERSECTION OF CURVE IN DEGREES
? 26.0


ENTER CHORD LENGTH IN FEET
? 570.0
```

STEP 4

The program proceeds on to the SUPERELEVATION design stage. User input to this stage consists of the design velocity of the curve. The user has the option of 30, 40, 50 or 60 miles per hour as this design velocity. Data is inputted as an integer in I2 format (i.e., 60). From this data, the program calculates Superelevation data and provides output in tabular form. From left to right this output reads as follows: curve midpoint station number, curve radius, length of curve, rate of superelevation, tangent length, beginning of curve (P.C.) station number, and end of curve (P.T.) station number.



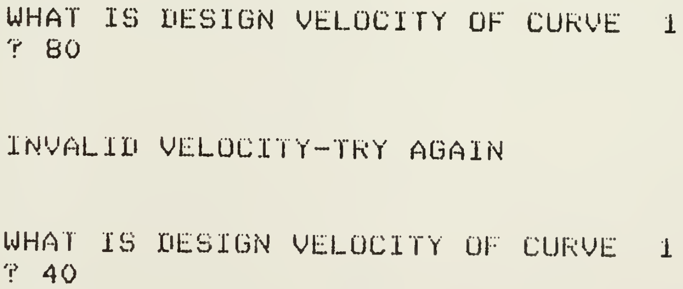
```
                                   SUPERELEVATION SUPERL

WHAT IS DESIGN VELOCITY OF CURVE  1
? 60
         STA NO      RAD       L OF C         SUPERL          TAN LEN    PC STA     PT STA

        132.947     1333.62  605.181       .04996069         307.891    129.921    139.052
```

STEP 4A

If the velocity input is not one of the optional velocities, 30, 40, 50 or 60 miles per hour, the program will reject the data and return the user to Step 4.



```
WHAT IS DESIGN VELOCITY OF CURVE   1
? 80


INVALID VELOCITY-TRY AGAIN


WHAT IS DESIGN VELOCITY OF CURVE   1
? 40
```

STEP 4B

If the velocity input results in a calculated superelevation rate of between 0.08 foot per foot and 0.10 foot per foot, the program will ask if snow is prevalent in the area. If snow is prevalent (YES), the program returns the user to Step 3 for realignment of the horizontal curve. If snow is not prevalent in the area (NO), the program accepts the calculated superelevation rate and continues on to the SOILS design stage.

```
WHAT IS THE DESIGN VELOCITY OF CURVE  1
? 60.0


WARNING IS SNOW PREVALENT?
ENTER 1  IF YES AND 2 IF NO.
? 1


ENTER STA NO OF TANGENT INTERSECTION OF CURVE  1
? 133.0
```

STEP 4C

If the velocity input results in a calculated superelevation rate greater than 0.10 foot per foot, the program will output a warning and return the user to Step 3 for realignment of the horizontal curve.

```
WHAT IS DESIGN VELOCITY OF CURVE  1
? 60


WARNING-RADIUS MUST INCREASE TO DECREASE SUPERL OF CURVE 1
WARNING D TOO HIGH REESTABLISH PC, PT, ANDC



ENTER STA NO OF TANGENT INTERSECTION OF CURVE  1
? 130.0


ENTER ANGLE OF INTERSECTION OF CURVE IN DEGREES
? 50.0


ENTER CHORD LENGTH IN FEET
? 600.0
```

STEP 5

The program proceeds on to the SOILS design stage. To utilize this subroutine, the user must first estimate the Average Daily Traffic (ADT) and percentage of heavy vehicles expected on the roadway. By entering the graph of Figure C-1 with the ADT and percentage of heavy vehicles, the user can determine a suitable road classification. By entering the graph of Figure C-2 with the percentage of heavy vehicles and the road classification, the user can select the proper design index. These parameters are more fully explained in Chapter VI, PROGRAM DESIGN. Both the road classification and design index will be used as inputs to the program later on.

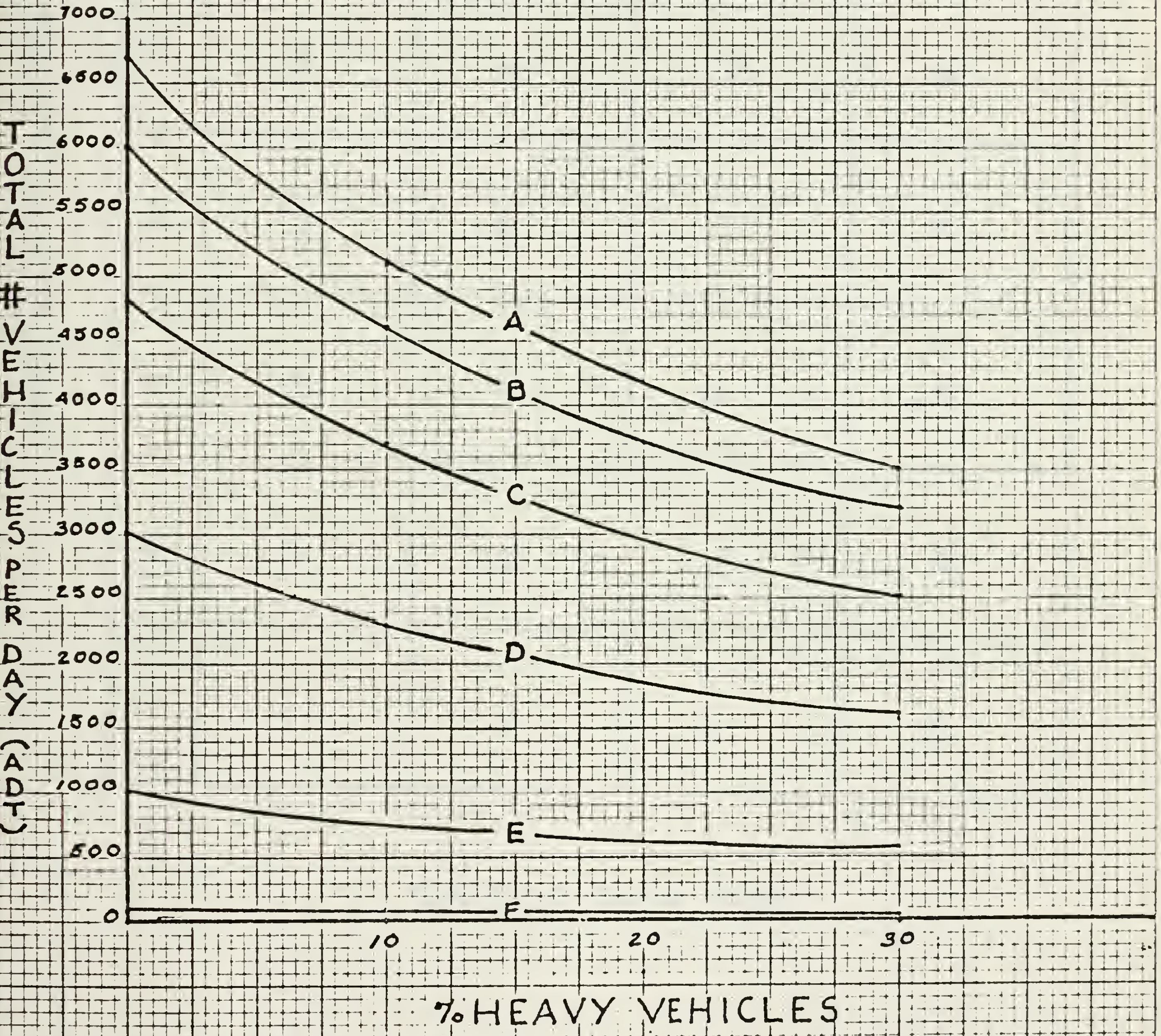


FIGURE C-1 - ROAD CLASSIFICATION[1]

	% HEAVY VEHICLES			
ROAD CLASSIFICATION	0	10	20	30
A	3	4	5	6
B	3	4	5	6
C	3	4	4	6
D	2	3	4	5
E	1	2	3	4
F	1	1	2	3

FIGURE C-2 -DESIGN INDEX [1]

STEP 6

Input the design index data of Step 5 into the program. This is input as an integer in I1 format (i.e., 6).

```
WHAT DESIGN INDEX IS TO BE USED?
? 6
```

STEP 7

Input the in-place density and California Bearing Ratio (CBR) of the existing subgrade into the program. The subgrade in-place density input data should be estimated as a percentage of maximum dry density utilizing a modified Proctor test (CE55). The subgrade CBR data should be estimated as if the subgrade were compacted from 90 to 95% of the maximum modified proctor density. Both data items must be input as real numbers (i.e., 70.0) as the program input format is F 4.1.

```
WHAT IS THE IN-PLACE (%CE55) OF THE SUBGRADE?
? 70.0
WHAT IS THE CBR OF THE SUBGRADE AT 90% TO 95% CE55?
? 5.0
```

STEP 7A

If the input in-place density of the subgrade is less than 20% or more than 100%, the program will output an error message and return the user to Step 7.

```
WHAT IS THE IN-PLACE (%CE55) OF THE SUBGRADE?
? 19.0
INPLACE DENSITY MUST BE GIVEN AS %CE55. TRY AGAIN.
WHAT IS THE IN-PLACE (%CE55) OF THE SUBGRADE?
? 20.0
```

STEP 7B

If the input CBR of the subgrade is less than 2 or more than 50, the program will output an error message and return the user to Step 7.

```
WHAT IS THE CBR OF THE SUBGRADE AT 90% TO 95% CE55?
? 120.0
VALUES FOR CBR SHOULD RANGE FROM ABOUT 2 TO 50. TRY AGAIN.
WHAT IS THE CBR OF THE SUBGRADE AT 90% TO 95% CE55?
? 15.0
```

STEP 8

Input the number of base, subbase, and select material layers to be utilized in the pavement design. This data is input as an integer in I1 format (i.e., 3).

```
HOW MANY TYPES OF BASE, SUBBASE, AND SELECT MATERIALS
DO YOU WISH TO CONSIDER?( DO NOT INCLUDE SUBGRADE OR PAVT)
? 3
```

STEP 8A

If the number of layers is greater than 7 or input as 0, the program will output a warning and return the user to Step 8.

```
HOW MANY TYPES OF BASE, SUBBASE, AND SELECT MATERIALS
DO YOU WISH TO CONSIDER?( DO NOT INCLUDE SUBGRADE OR PAVT)
? 8
THIS PROGRAM WILL HANDLE UP TO 7 DIFFERENT SOILS.
THIS SHOULD BE MORE THAN SUFFICIENT.
HOW MANY TYPES OF BASE, SUBBASE, AND SELECT MATERIALS
DO YOU WISH TO CONSIDER?( DO NOT INCLUDE SUBGRADE OR PAVT)
? 3
```

STEP 9

Input the CBR values for the base course, the subbase, and each of the select materials chosen. These CBRs should be input as real numbers (i.e., 82.0) as the program input format is F5.1.

```
WHAT IS THE CBR VALUE OF THE BASE COURSE?
? 82.0
WHAT IS THE NEXT HIGHEST CBR?
? 56.0
WHAT IS THE NEXT HIGHEST CBR?
? 43.0
```

STEP 9A

If the input CBR values are less than 2 or greater than 100, the program will output an error message and return the user to Step 9.

```
WHAT IS THE CBR VALUE OF THE BASE COURSE?
? 99.0
WHAT IS THE NEXT HIGHEST CBR?
? 101.0
VALUES FOR CBR SHOULD RANGE FROM ABOUT 2 TO 100.
TRY AGAIN.
```

STEP 9B

If the CBR values are not input in descending order, the program will output an error message and return the user to Step 9.

```
WHAT IS THE NEXT HIGHEST CBR?
? 90.0
WHAT IS THE NEXT HIGHEST CBR?
? 95.0
CBR VALUES WERE NOT GIVEN IN DESCENDING ORDER.
TRY AGAIN.
WHAT IS THE CBR VALUE OF THE BASE COURSE?
? 99.0
WHAT IS THE NEXT HIGHEST CBR?
? 95.0
WHAT IS THE NEXT HIGHEST CBR?
? 90.0
WHAT CLASSIFICATION IS TO BE USED?
A=1,B=2,C=3,D=4,E=5,F=6
? 3
```

STEP 10

The next data to be input is the road classification. This data is input as an integer in I1 format (i.e., 3). After this data has been input, the program outputs the minimum thickness requirements of the various layers of the pavement structure, including asphaltic pavement. The program also outputs a design cross section of a typical pavement section. This cross section is roughly scaled such that one inch of cross section material is represented by four computer lines.

```
WHAT CLASSIFICATION IS TO BE USED?
A=1,B=2,C=3,D=4,E=5,F=6
? 3


MIN THICKNESS RQD ABOVE SOIL WITH CBR= 5.0 IS 22.0
MIN THICKNESS RQD ABOVE SOIL WITH CBR=43.0 IS  4.0
MIN THICKNESS RQD ABOVE SOIL WITH CBR=56.0 IS  3.0
THE MIN RQD THICKNESS OF PAVT IS 3.0
MIN RQD THICKNESS OF BASE COURSE IS 4 INCHES
*************************************************************

                      DESIGN PROFILE
 DEPTH
(INCHES)
    0            ======= TOP OF PAVEMENT =======


                3.0 INCHES OF ASPHALTIC PAVEMENT


  3.0      -------------------------------------



                4.0 INCHES OF BASE COURSE              CBR=82.0



  7.0      -------------------------------------



                4.0 INCHES OF SUBBASE MATERIAL         CBR=56.0



 11.0      -------------------------------------






               11.0 INCHES OF SELECT MATERIAL          CBR=43.0






 22.0      -------------------------------------
                     SUBGRADE                          CBR= 5.0
```

STEP 11

The last data input into the SOILS subroutine is a rating of the structural capability of the subgrade. The user indicates whether the soil is cohesive (silt or clay) with a Plastic Index (PI) greater than five or not. An index of this parameter is inputted as an integer in I1 format (3 or 4). After this data has been received, the program outputs the soil compaction requirements, and the design cross sections for both fill and cut sections. These are presented in the same, scaled cross section format as was discussed in Step 11. The compaction requirements schedule indicates the compaction as a percentage of the modified Proctor test (CE 55). The cut and fill cross sections indicate the quantity (in inches) and percent compaction for each soil layer being designed. In addition, the output provides special instructions, as necessary, with regard to the pavement surface treatment and subgrade.

```
**************************************************
IF THE SUBGRADE IS COHESIVE(PI>5),TYPE 3
IF THE SUBGRADE IS NON-COHESIVE,TYPE 4.
? 4
**************************************************
         COMPACTION REQUIREMENTS (WRITTEN)

DEPTH     .
(INCHES)        -====== TOP OF PAVEMENT =-====-=




              100.0% CBR=82.0







   7.0    ------------------------------------

            . 100.0% CBR-56.0

  11.0    ------------------------------------








              100.0% CBR=43.0










  22.0    ------------------------------------
               95.0% CBR- 5.0
              TDF (TO DEPTH OF FILL)

**************************************************
```

```
*************************************************************
                    FINAL DESIGN
                  FOR FILL SECTIONS
 DEPTH
(INCHES)   ============== TOP OF PAVEMENT ==============


           3.0 INCHES OF ASPHALTIC PAVEMENT



  3.0     ------------------------------------

           4.0 INCHES,CBR= 82.0 AT 100% CE55

  7.0     ------------------------------------

           4.0 INCHES,CBR= 56.0 AT 100% CE55

 11.0     ------------------------------------





          11.0 INCHES,CBR= 43.0 AT 100% CE55







 22.0     ------------------------------------
           TO DEPTH OF FILL,CBR= 5.0 AT 95.0% CE55
  TDF       ----------------------------------------------
          6 INCHES,SCARIFY AND COMPACT IN PLACE AT 75.0% CE55
          -----------------------------------------------
          CBR= 5.0 IN-PLACE DENSITY=70.0% CE55
*************************************************************
```

```
****************************************************************
                    FINAL DESIGN FOR CUT SECTIONS
 DEPTH
(INCHES)   ============= TOP OF PAVEMENT =============

            3.0 INCHES OF ASPHALTIC PAVEMENT

  3.0     -----------------------------------

            4.0 INCHES,CBR= 82.0 AT 100% CE55

  7.0     -----------------------------------

            4.0 INCHES,CBR= 56.0 AT 100% CE55

 11.0     -----------------------------------



           11.0 INCHES,CBR= 43.0 AT 100% CE55



 22.0     -----------------------------------


           SUBGRADE REMOVED AND REPLACED AT 100.0% CE55


 28.0     -----------------------------------



           SUBGRADE REMOVED AND REPLACED AT  95.0% CE55



 40.0     -----------------------------------



           SUBGRADE REMOVED AND REPLACED AT  90.0% CE55



 60.0     -----------------------------------

           SCARIFY AND COMPACT IN-PLACE AT  85.0% CE55

 66.0     -----------------------------------
           CBR= 5.0     IN PLACE DENSITY= 70.0% CE55
****************************************************************
THIS COMPLETES THE SOILS DESIGN
```

STEP 12

The program initializes the VERTICAL ALIGNMENT design stage by outputting comments. These comments are designed to aid the user in laying out the road section. The first data to be input is the number of stations to be considered in the road section. This number should be input as an integer (i.e., 16) as I2 input format was used. A maximum of fifty stations can be designed at one session.

```
THIS SUBROUTINE WILL CALCULATE THE CENTERLINE
ELEVATION OF THE FINISHED GRADE. YOU MUST SUPPLY THE
ACTUAL ELEVATIONS OF THE LEFT SIDE DITCH BACKSLOPE,
CENTERLINE,AND THE RIGHT SIDE DITCH BACKSLOPE. THE
TERMINAL POINT FOR BACKSLOPES IS 20 FEET LEFT OR
RIGHT OF THE CENTERLINE. ENSURE THAT THE PC, PT, AND
MIDPOINTS OF ANY CURVES IN THIS SECTION ARE INCLUDED.

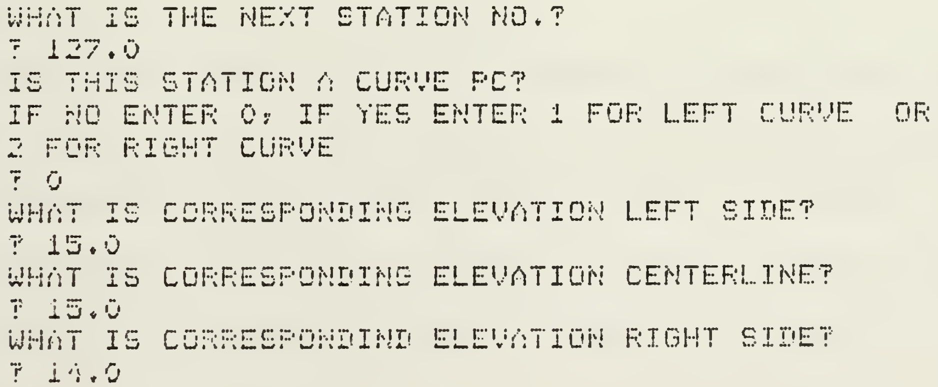
HOW MANY STATIONS IN THIS SECTION? MAX=50

? 16
```

STEP 13

Next the program requests data on each of the stations being designed. This data consists of the station number, the horizontal alignment, and the elevations of the existing road section. The station numbers should be input as real numbers (i.e., 127.0) as the program input format is F7.3. The station numbers and other station data, must be input in ascending order for the program to work properly. Further, it is important that the beginning station be input. As the horizontal alignment input

to the vertical alignment subroutine, the program asks the user whether the station number being input is a P.C. of a horizontal curve. If it is, the program requests input as to whether the horizontal curve bears to the right or left. This horizontal curve data is used as an index by the program to apply the superelevation rates calculated in the SUPERELEVATION design stage to the road cross sections following the P.C. stations. As the superelevation rates are stored in an array indexed by the horizontal curve number, if P.C. stations are not input in ascending order or if one of the P.C. stations is omitted, the wrong superelevation rates will be applied to the cross sections. The horizontal curve data is input as an integer (0, 1 or 2) as the program input format is I2. The elevations of the existing road cross section are input as three data points. These data points are the elevation of the road on the centerline of the horizontal alignment, and the elevations of the road section eight feet to the left and the right of this centerline. All three elevations should be input as real numbers (i.e., 15.0) as the program input format is F7.3.



```
WHAT IS THE NEXT STATION NO.?
? 127.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 15.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 15.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 14.0
```

STEP 13A

After input for every station in the vertical alignment road section has been completed, the program outputs data on the existing conditions of the proposed road section. This output is in tabular form. From left to right this output reads as follows: station number, left side elevation, centerline elevation, right side elevation and slope. The slope outputted is the slope between the centerline elevations of adjacent stations in percentage.

```
STA NO          LS ELEV          CL ELEV          RS ELEV          SLOPE

127.000         15.000           15.000           14.000           0.000
128.000         15.000           15.000           14.000           0.000
129.000         16.000           16.000           16.000           1.000
129.920         16.000           16.800           18.000            .870
130.000         17.000           17.000           15.000           2.500
131.000         17.000           17.000           16.000           0.000
132.000         17.000           19.000           17.000           2.000
133.000         10.000           20.000           17.000           1.000
134.000         19.000           21.000           19.000           1.000
135.000         20.000           20.500           21.000           -.500
136.000         20.500           20.000           21.000           -.500
137.000         19.000           19.000           20.000          -1.000
138.000         18.000           18.000           19.000          -1.000
139.000         17.000           18.000           18.000           0.000
140.000         17.000           18.000           18.000           0.000
141.000         18.500           18.500           17.500            .500
```

STEP 14

Next the program asks the user to review the existing slopes and determine the final design grades between station centerlines. It is important at this point for the user to consider the quantities of cut and fill in his design. A design grade sufficiently different from the existing ground slope will yield a final design

centerline elevation much higher or much lower than the existing ground centerline. This in turn will cause a large quantity of cut or fill for that road section. The user should try to minimize cut and fill quantities if practical. Another point the user should consider is the rollercoaster effect. The program will design parabolic vertical curves whenever two consecutive design grades between stations are unequal. If the user tries too hard to follow the existing ground slope in choosing his design grades, every design grade chosen will be unequal to the adjoining design grades. This will yield a vertical curve at nearly every station and a very uneven road. Therefore the user must use sound engineering judgement in the selection of his design grades. The design grades should be inputted as a real number (i.e., -1.0%) as the program input format is F7.3.

```
YOU MUST REVIEW THE SLOPE AND DETERMINE THE
DESIRED GRADE OR GRADES.

WHAT IS THE GRADE FROM 127.00 TO 128.00
? 1.0
WHAT IS THE GRADE FROM 128.00 TO 129.00
? 1.0
WHAT IS THE GRADE FROM 129.00 TO 129.92
? 1.0
WHAT IS THE GRADE FROM 129.92 TO 130.00
? 1.0
WHAT IS THE GRADE FROM 130.00 TO 131.00
? 1.0
WHAT IS THE GRADE FROM 131.00 TO 132.00
? -0.5
WHAT IS THE GRADE FROM 132.00 TO 133.00
? -0.5
WHAT IS THE GRADE FROM 133.00 TO 134.00
? -0.5
WHAT IS THE GRADE FROM 134.00 TO 135.00
? -0.5
WHAT IS THE GRADE FROM 135.00 TO 136.00
? -0.5
WHAT IS THE GRADE FROM 136.00 TO 137.00
? -0.5
WHAT IS THE GRADE FROM 137.00 TO 138.00
? 0.0
WHAT IS THE GRADE FROM 138.00 TO 139.00
? 0.0
WHAT IS THE GRADE FROM 139.00 TO 140.00
? 0.0
WHAT IS THE GRADE FROM 140.00 TO 141.00
? 0.0
```

STEP 15

Next the program asks the user to input the final grade centerline elevation of the first station in the vertical alignment road section. This should be input as a real number (i.e., 15.0) as the program input format is F7.3.

```
WHAT IS THE FINAL GRADE CENTERLINE ELEVATION
OF THE FIRST STATION ?
? 15.0
```

STEP 16

Finally, the program identifies the tangent intersection stations of the design grades (V), and asks the user to input the number of stations (B) the user desires in the vertical curve at each intersection station. The value of B will be the total length of the vertical curve, with half this length coming before the intersection station and half after the intersection point. This data should be input as a real number (i.e., 2.0 stations) as the program input format is F7.3.

```
A VERTICAL CURVE IS NECESSARY AT STA 131.00
HOW MANY STATIONS DO YOU WANT TO INCLUDE IN THE CURVE ?
? 2.0

A VERTICAL CURVE IS NECESSARY AT STA 137.00
HOW MANY STATIONS DO YOU WANT TO INCLUDE IN THE CURVE ?
? 4.0
```

STEP 16A

Output for both the VERTICAL ALIGNMENT and CROSS SECTION design stages is as shown below. The program automatically calculates a standard cross section based on the final design centerline elevations. In those road sections where a horizontal curve creates the need for superelevation, the program automatically adjusts the road cross sections to transition from a standard crowned road at the P.C. and P.T. points to a road section of full superelevation at the horizontal curve midpoint station. As this tabular output is rather long, the cross section data has been broken down into two schedules. The first schedule consists of the

following: station number, left backside ditch elevation, left side ditch elevation, left side shoulder elevation, left side pavement edge elevation, and the pavement centerline elevation. The second schedule provides the station number, the right side pavement edge elevation, the right side shoulder elevation, the right side ditch elevation, and the right backside ditch elevation. The ditch and backside ditch elevaltions will be adjusted later on in the program by the intersection point and cross section subroutines.

```
     ********************************** CROSS SECTION **********************************

STA                 BACKL               DITL                SHL                 PVMTL               CL

127.000              16.209              13.982              14.265              14.517              15.000
128.000              17.209              14.982              15.265              15.517              16.000
129.000              18.209              15.982              16.265              16.517              17.000
129.920              19.129              16.902              17.185              17.437              17.920
130.000              19.209              16.982              17.265              17.517              18.000
131.000              19.834              17.607              17.890              18.142              18.625
132.000              19.709              17.482              17.765              18.017              18.500
133.000              19.209              16.982              17.265              17.517              18.000
134.000              18.709              16.482              16.765              17.017              17.500
135.000              18.209              15.982              16.265              16.517              17.000
136.000              17.772              15.544              15.828              16.080              16.563
137.000              17.459              15.232              15.515              15.767              16.250
138.000              17.272              15.044              15.328              15.580              16.063
139.000              17.209              14.982              15.265              15.517              16.000
140.000              17.209              14.982              15.265              15.517              16.000
141.000              17.209              14.982              15.265              15.517              16.000

STA                 PVMTR               SHR                 DITR                BACKR

127.000              14.517              14.265              12.767              14.994
128.000              15.517              15.265              13.767              15.994
129.000              16.517              16.265              14.767              16.994
129.920              17.437              17.185              15.687              17.914
130.000              17.517              17.265              15.767              17.994
131.000              18.142              17.890              16.392              18.619
132.000              18.017              17.765              16.267              18.494
133.000              17.517              17.265              15.767              17.994
134.000              17.017              16.765              15.267              17.494
135.000              16.517              16.265              14.767              16.994
136.000              16.080              15.828              14.329              16.557
137.000              15.767              15.515              14.017              16.244
138.000              15.580              15.328              13.829              16.057
139.000              15.517              15.265              13.767              15.994
140.000              15.517              15.265              13.767              15.994
141.000              15.517              15.265              13.767              15.994

*****************************************************************
```

STEP 17

The INTERSECTION POINT design stage is computed by the subroutine INSECT. The program initializes this design stage with some comments and then requests input of the slope grade at each station for both the right and left hand side of the road. Input consists of an integer (i.e., -2) as the program input format is I2. The INSECT subroutine internally converts this data to a ratio of the rise over the run (i.e., 2 means 1:2 slope). The subroutine then compares the right/left design shoulder elevation with right/left existing ground elevation to determine whether the cross section is in cut or fill. From this calculation, the program is able to determine the toe of the slope in a fill section by applying the slope grade downward from the road shoulder elevation. If the section is found to be in cut, the program applies the slope upward from the backside ditch elevation to the top of slope.

```
******************************************************************

========================================================
SUBROUTINE INSECT COMPUTES THE INTERSECTION OF THE
SIDESLOPES WITH THE EXISTING GROUND AT EACH STA.
INPUT A SLOPE GRADE IN RESPONSE TO THE PROGRAMS QUESTIONS.
USE ANY WHOLE NUMBER UP TO TWO DIGITS.
I.E.  USE 2 FOR 1:2 OR 4 FOR 1:4

WHAT IS THE RIGHT SLOPE GRADE AT STA. 127.00?
?  3

WHAT IS THE RIGHT SLOPE GRADE AT STA. 128.00?
?  3

WHAT IS THE RIGHT SLOPE GRADE AT STA. 129.00?
?  3

WHAT IS THE RIGHT SLOPE GRADE AT STA. 129.92?
?  3

WHAT IS THE RIGHT SLOPE GRADE AT STA. 130.00?
?  2

WHAT IS THE RIGHT SLOPE GRADE AT STA. 131.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 127.00?
?  3

WHAT IS THE LEFT SLOPE GRADE AT STA. 128.00?
?  3

WHAT IS THE LEFT SLOPE GRADE AT STA. 129.00?
?  3

WHAT IS THE LEFT SLOPE GRADE AT STA. 129.92?
?  3

WHAT IS THE LEFT SLOPE GRADE AT STA. 130.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 131.00?
?  2
```

STEP 17A

After the program has determined whether the road section is in cut or fill, the program calculates the right and left existing ground cross section slope. This is determined by calculating the difference in the right/left existing ground elevations over the horizontal distance between these elevation points (28 feet).

If the existing ground cross section slope if found to be equal to the design slope grade, the two grades will be parallel and no intersection points could be calculated. The INSECT subroutine checks this possibility, and if found, outputs an error message and returns the user to Step 17.

```
WHAT IS THE RIGHT SLOPE GRADE AT STA. 100.00?
? 2


THE SLOPE GRADE CHOSEN IS PARRALLEL WITH
THE EXISTING GROUND. CHOOSE ANOTHER SLOPE GRADE.

WHAT IS THE RIGHT SLOPE GRADE AT STA. 100.00?
? 1
```

STEP 17B

The INSECT subroutine determines the top/toe of slope by calculating the elevations of the design road section at the slope and the extrapolated existing ground, in one foot horizontal increments. At some point these two slopes will cross if they are not parallel. The intersection point of the two slopes is defined by an elevation and a distance from the centerline. This data is then output by the INSECT subroutine in the tabular format shown below.

```
================= INTERSECTION POINTS ================

  STA NO       LEFT HAND SIDESLOPE      RIGHT HAND SIDESLOPE
               GRADE   ELEV    DIST     GRADE   ELEV    DIST

  127.00         3    15.00   34.10       3    13.93   34.10
  128.00         3    15.00   37.10       3    13.89   37.10
  129.00         3    16.00   37.10       3    16.00   31.10
  129.92         3    15.87   40.10       3    18.91   31.10
  130.00         2    17.00   34.10       2    14.72   36.10
  131.00         2    17.00   34.10       2    15.89   34.10
  132.00         2    16.79   34.10       2    16.86   32.10
  133.00         2     4.66   58.10       2    16.79   32.10
  134.00         2    19.71   30.10       2    19.49   32.10
  135.00         2    20.21   32.10       2    21.99   38.10
  136.00         2    20.77   34.10       2    21.56   38.10
  137.00         2    19.46   32.10       2    20.24   36.10
  138.00         2    18.27   30.10       2    20.06   36.10
  139.00         2    18.21   30.10       2    18.99   34.10
  140.00         2    18.21   30.10       2    18.99   34.10
  141.00         2    19.21   32.10       2    17.99   32.10

=====================================================
```

STEP 17C

The CROSS SECTIONAL AREA design stage is computed by the XSECT subroutine. No additional input is required from the user. Subroutine XSECT collects the road cross section elevation data produced in the CROSS SECTION and INTERSECTION POINT design stages and develops cross section coordinate data for each station. The program then computes the cross sectional area (in square feet) of cut or fill at each station by means of the criss-cross method. Finally the program computes volume and cumulative volume (in cubic yards) between each of the stations. The volume calculation is performed using the average end area method. The cross sectional areas, the volumes and the cumulative volumes are assigned a sign such that fill is represented by a + sign and cut is represented by a - sign. The output is presented in tabular form as shown on the following page.

```
*=====================================================
SUBROUTINE XSECT COMPUTES CROSS SECTIONAL AREAS
FOR EACH STA, VOLUME BETWEEN STAS, AND CUMULATIVE
VOLUME. FILL AREAS ARE GIVEN A + SIGN AND CUT AREAS
ARE INDICATED BY A - SIGN.


 ===================== VOLUMES =====================


   STA NO  CROSS SECTION  VOLUME BETWEEN  CUMULATIVE
              AREAS(SF)     STATIONS(CY)   VOLUME(CY)

                                   0.00         0.00
   127.00       -10.69
                                  85.41        85.41
   128.00        56.81
                                 176.10       261.52
   129.00        38.28
                                 114.66       376.18
   129.92        29.02
                                  14.60       390.78
   130.00        69.55
                                 297.11       687.89
   131.00        90.88
                                 159.29       847.18
   132.00        -4.87
                                -199.79       647.39
   133.00      -103.02
                                -553.85        93.54
   134.00      -196.05
                                -853.92      -760.38
   135.00      -265.06
                               -1007.80     -1768.18
   136.00      -279.15
                                -927.93     -2696.11
   137.00      -221.93
                                -743.30     -3439.41
   138.00      -179.45
                                -638.72     -4078.13
   139.00      -165.46
                                -612.82     -4690.94
   140.00      -165.46
                                -640.29     -5331.23
   141.00      -180.30

 ==================================================
```

STEP 17D

The final design stage, MASS BALANCE is computed by the MASBAL subroutine. No additional input is required from the user. Subroutine MASBAL collects the cumulative volume data produced in the CROSS SECTIONAL AREA design stage and sorts this data in descending order. The program then outputs the maximum and minimum cumulative volumes and their station locations in narrative form. This is shown below. Finally, the MASBAL subroutine routes the cumulative volume and station data to the VERSATEC plotter. A sample of this output is shown on below.

```
==========================================================
SUBROUTINE MASBAL FINDS MAXIMUM AND MINIMUM
CUMULATIVE VOLUMES, AND IDENTIFIES THEIR STATION
LOCATION POINTS. IT ALSO PLOTS A MASS DIAGRAM ON
THE VERSATEC PLOTTER, NO INPUT IS NECESSARY.


THE MAXIMUM CUMULATIVE VOLUME IS    847.18 CUBIC YARDS
THIS OCCURS AT STATION 127.00


THE MINIMUM CUMULATIVE VOLUME IS  -5331.23 CUBIC YARDS
THIS OCCURS AT STATION 141.00



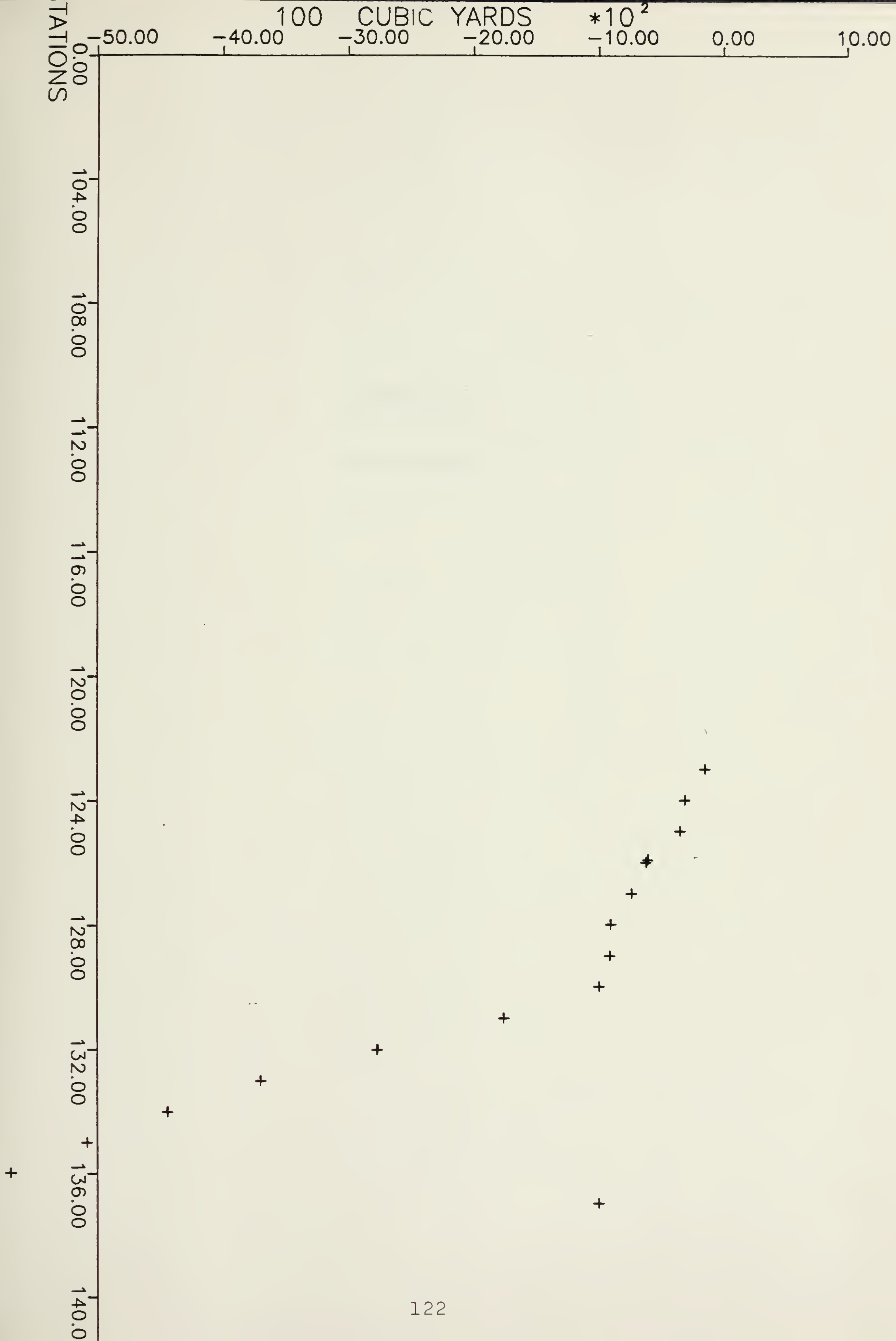
GO TO THE PLOTTER BIN AND REMOVE OUTPUT (MASS DIAGRAM)



==========================================================

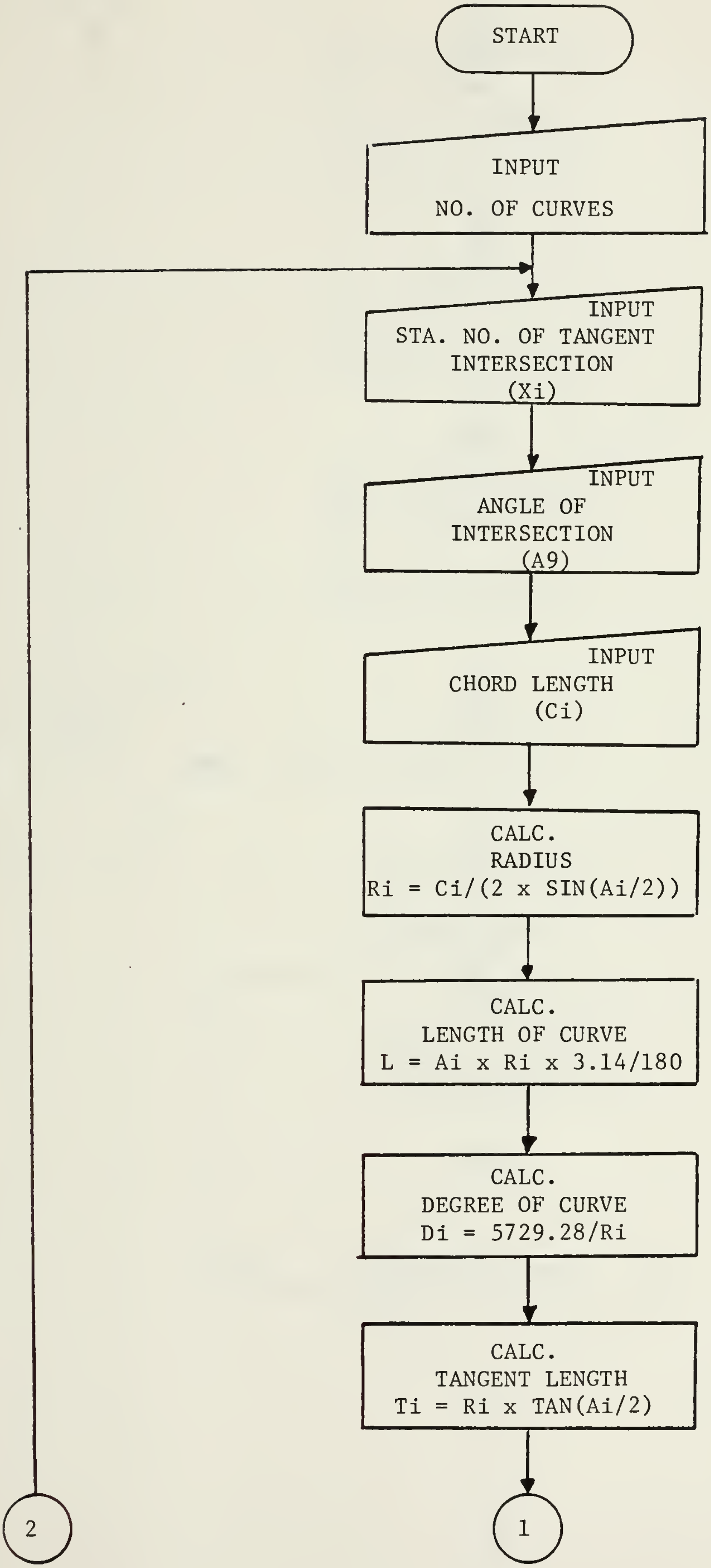

************************************************************
THIS PROGRAM WILL END
     3.232 CP SECONDS EXECUTION TIME.
/PLOTCV(TAPE9)
 PLOT.     81/11/03. 12.21.35.
/BYE

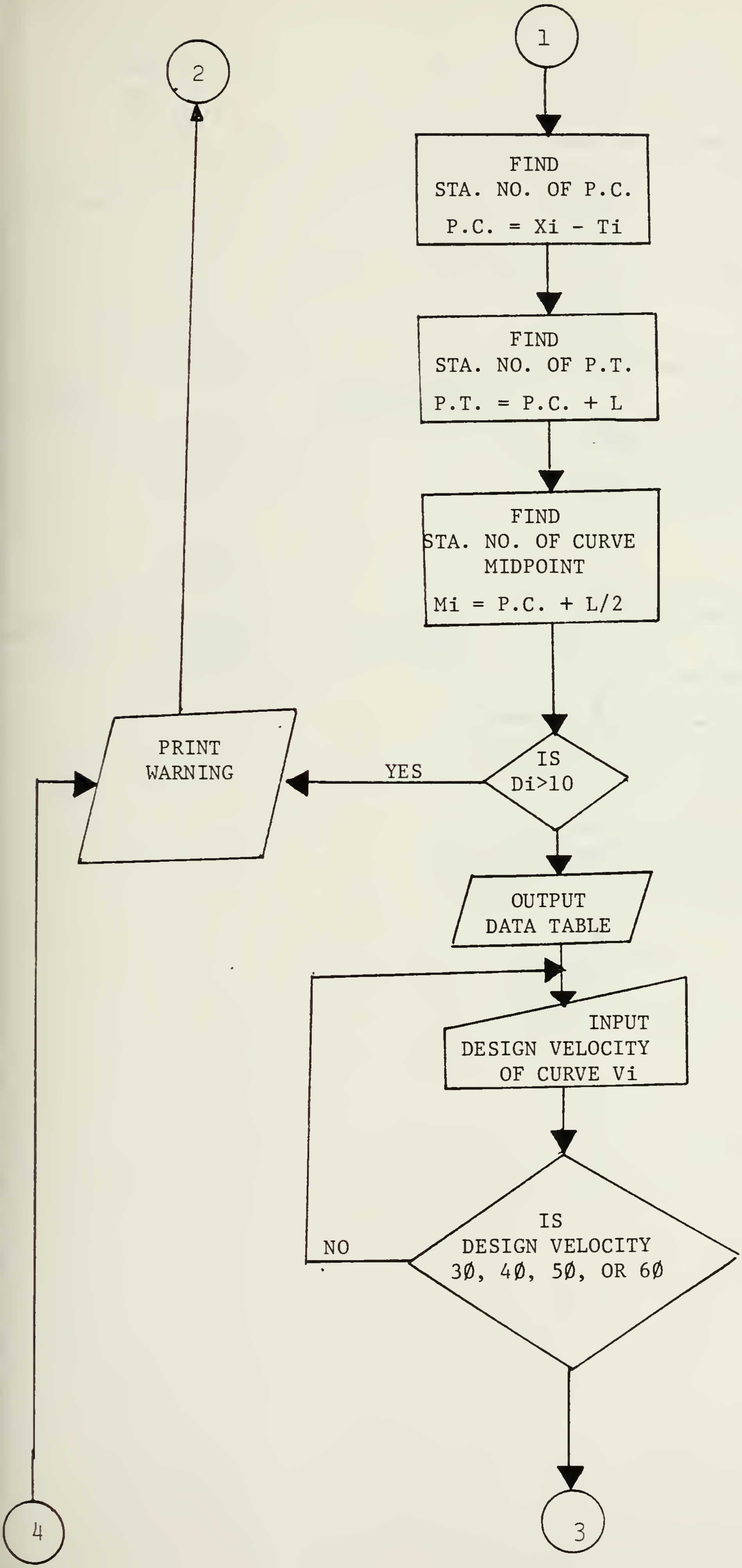
CE513AA   LOG OFF    12.23.08.
CE513AA   SRU     54.444 UNTS.
```

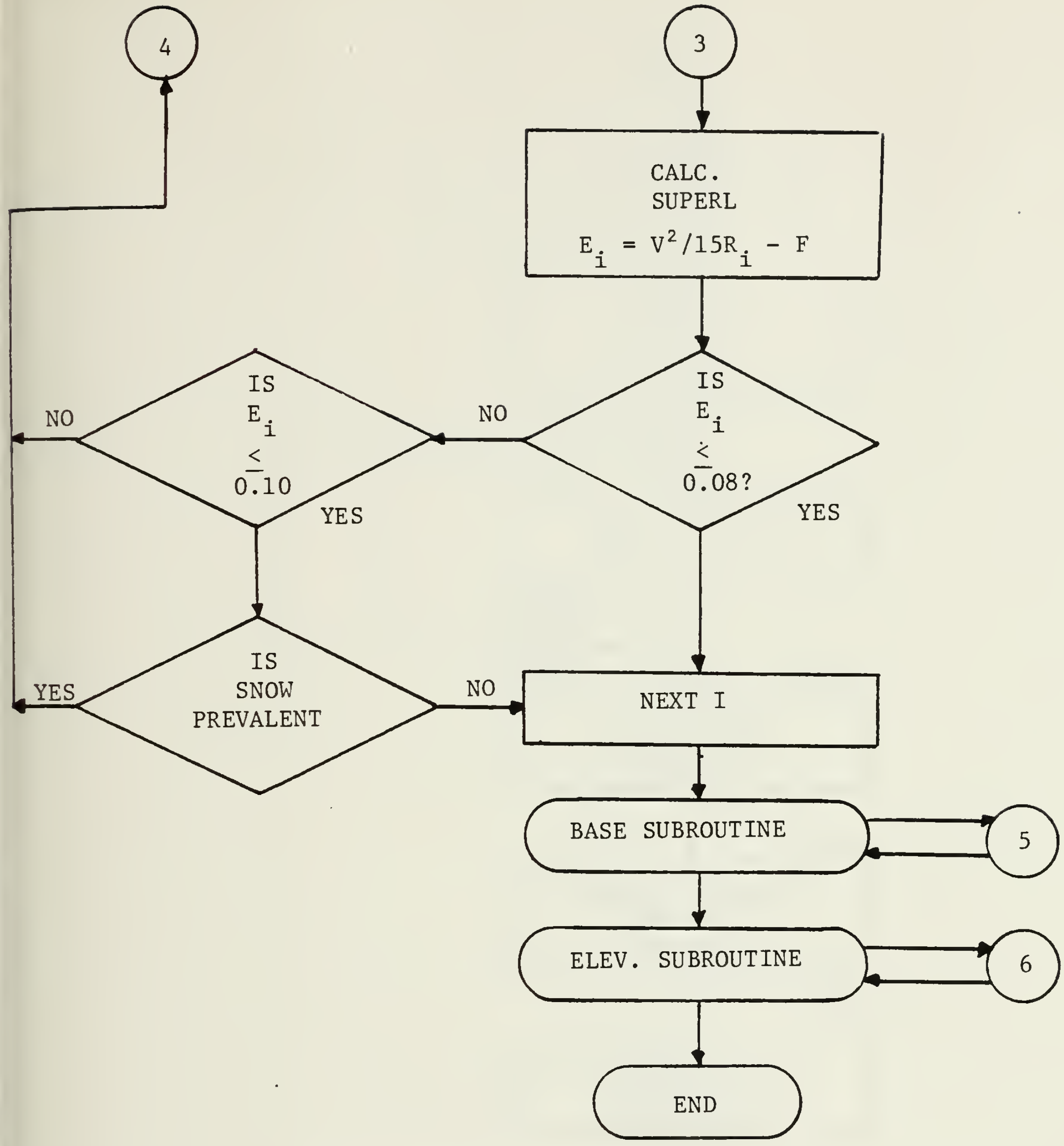

100 CUBIC YARDS *10²
−50.00
−40.00
−30.00
−20.00
−10.00
0.00
10.00
TATIONS
0.00
104.00
108.00
112.00
116.00
120.00
124.00
128.00
132.00
136.00
140.0

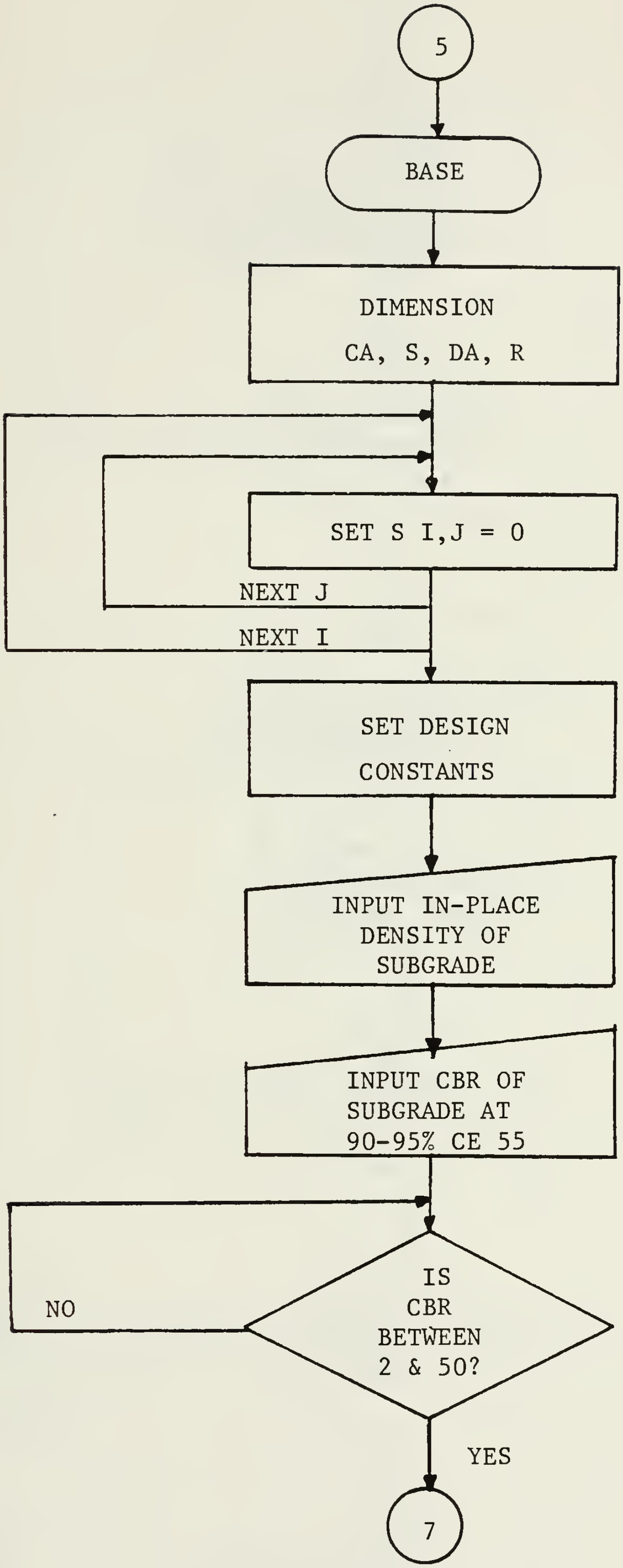
APPENDIX D

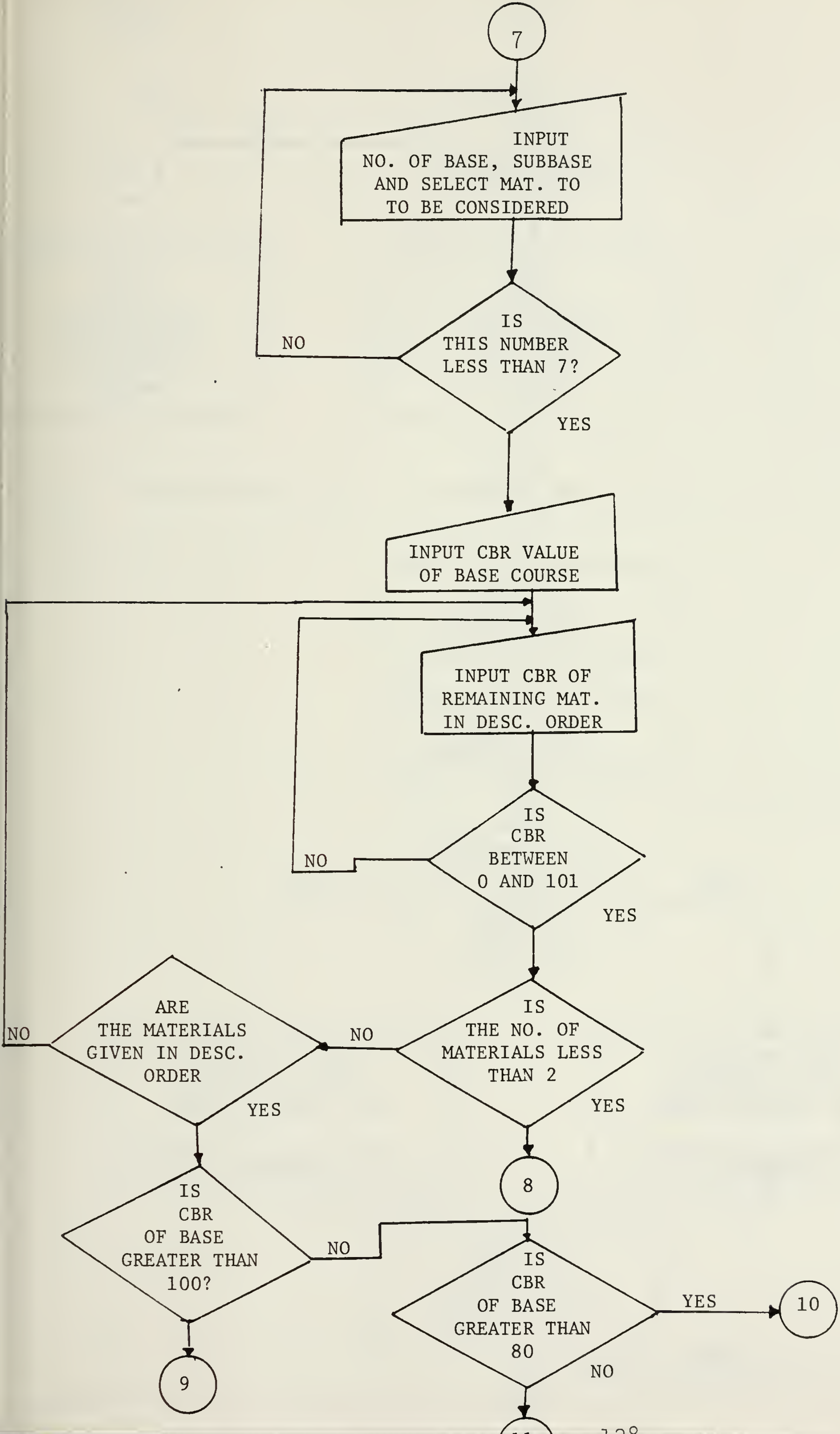
FLOW CHART

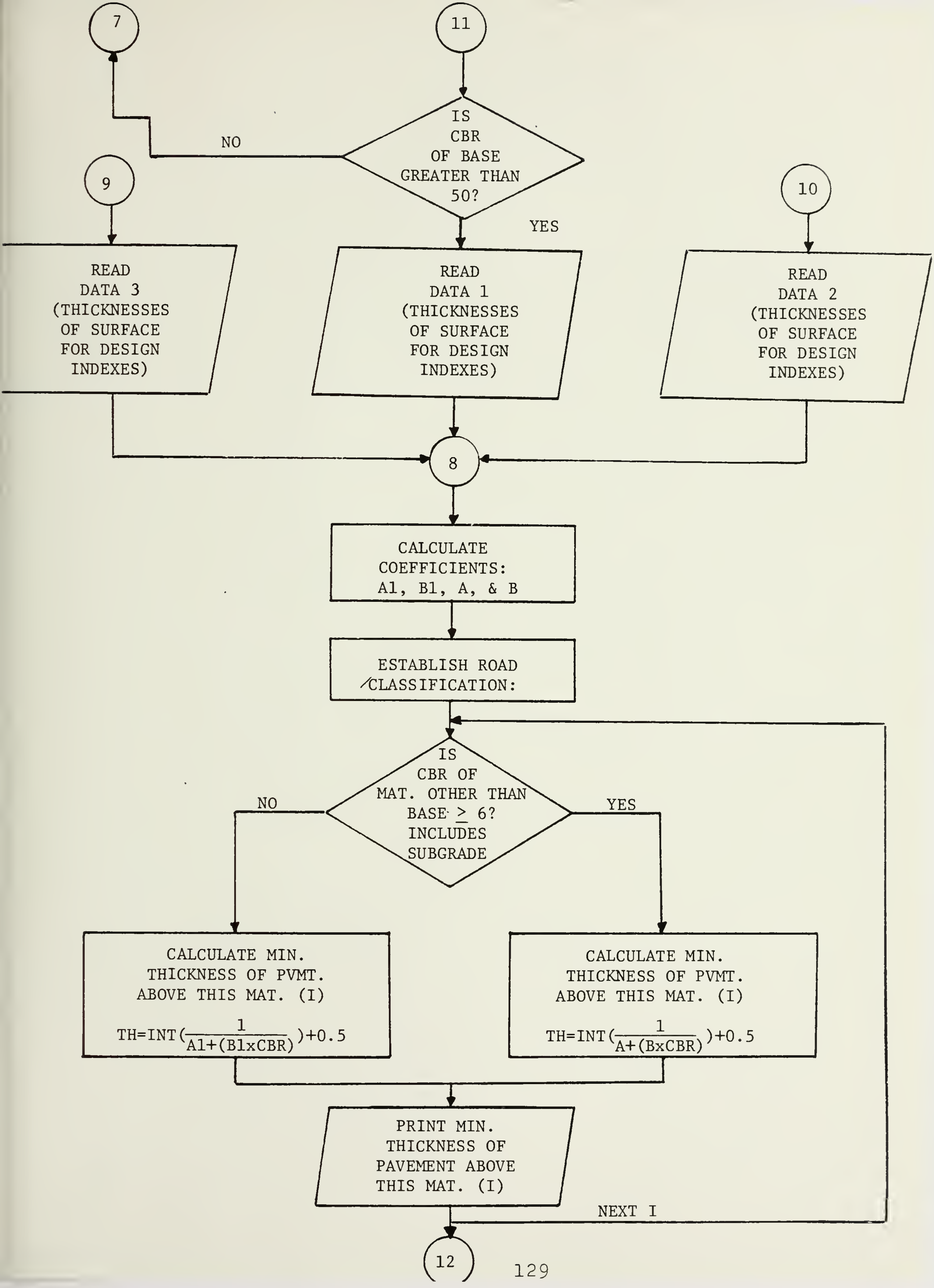

START
INPUT
NO. OF CURVES
INPUT
STA. NO. OF TANGENT
INTERSECTION
(Xi)
INPUT
ANGLE OF
INTERSECTION
(A9)
INPUT
CHORD LENGTH
(Ci)
CALC.
RADIUS
Ri = Ci/(2 x SIN(Ai/2))
CALC.
LENGTH OF CURVE
L = Ai x Ri x 3.14/180
CALC.
DEGREE OF CURVE
Di = 5729.28/Ri
CALC.
TANGENT LENGTH
Ti = Ri x TAN(Ai/2)
2
1

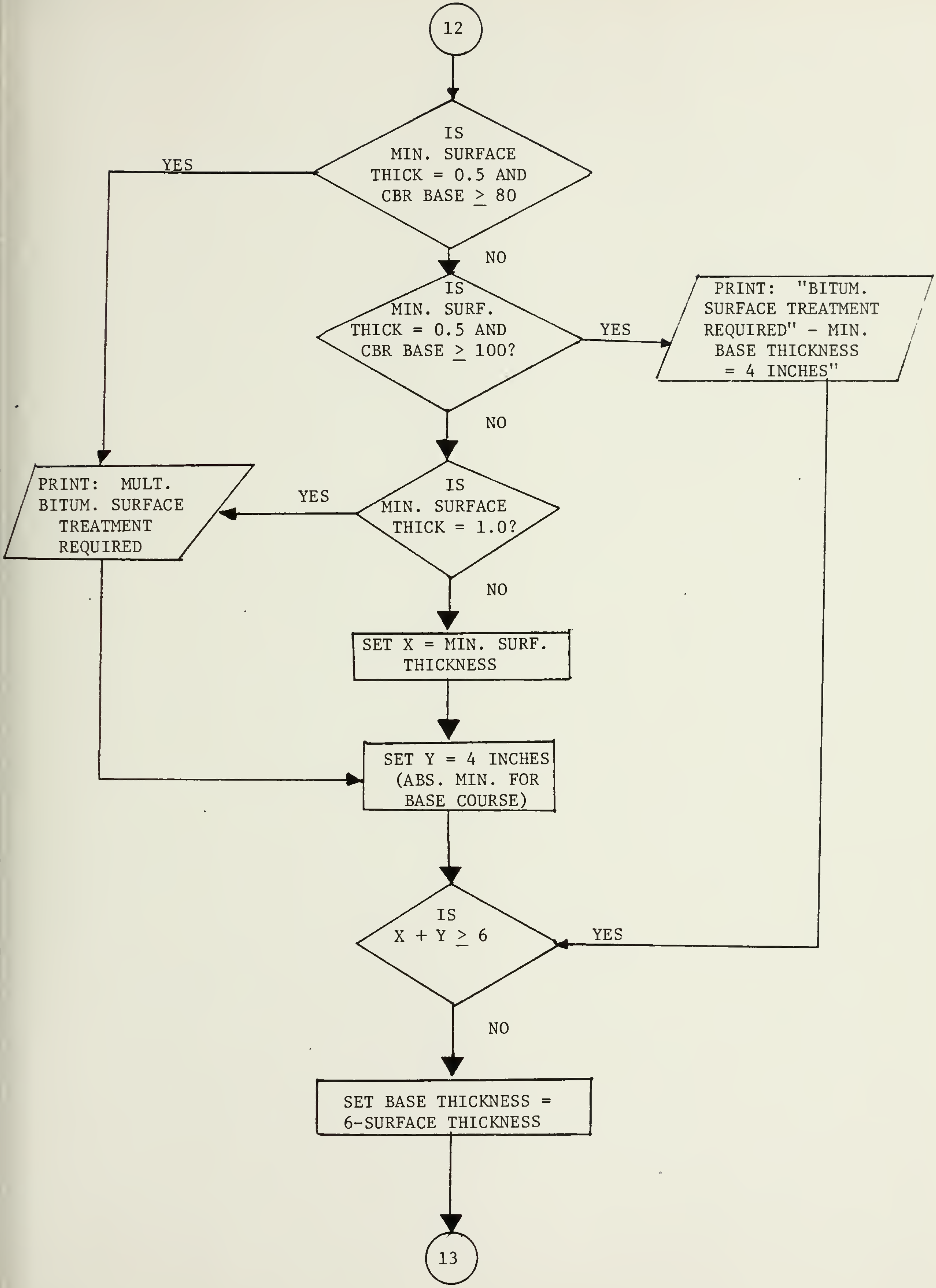

1
2
FIND
STA. NO. OF P.C.
P.C. = Xi - Ti
FIND
STA. NO. OF P.T.
P.T. = P.C. + L
FIND
STA. NO. OF CURVE
MIDPOINT
Mi = P.C. + L/2
PRINT
WARNING
YES
IS
Di>10
OUTPUT
DATA TABLE
INPUT
DESIGN VELOCITY
OF CURVE Vi
NO
IS
DESIGN VELOCITY
30, 40, 50, OR 60
4
3

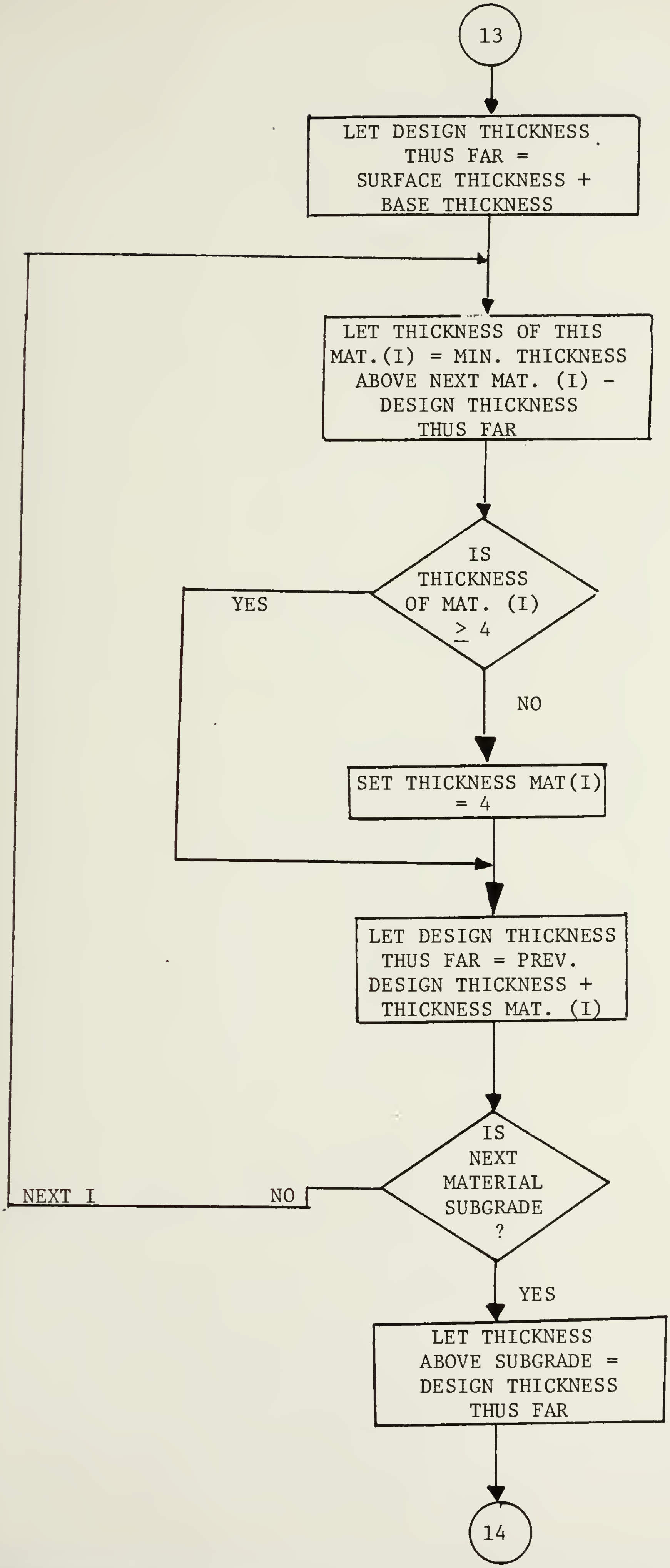

4
3
CALC.
SUPERL
$E_i = V^2/15R_i - F$
IS $E_i \le 0.08$?
NO
YES
IS $E_i \le 0.10$
NO
YES
IS SNOW PREVALENT
YES
NO
NEXT I
BASE SUBROUTINE
5
ELEV. SUBROUTINE
6
END

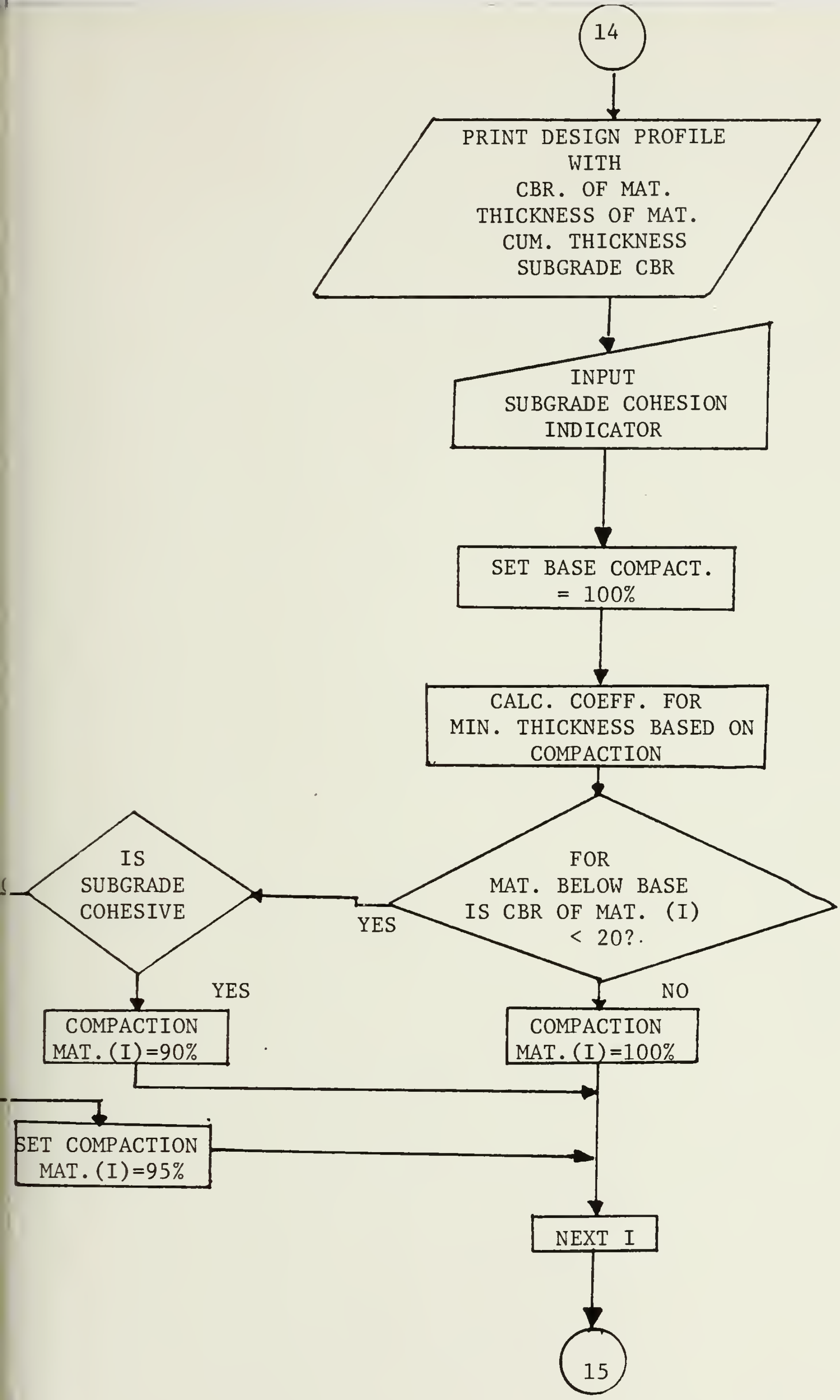

5
BASE
DIMENSION
CA, S, DA, R
SET S I,J = 0
NEXT J
NEXT I
SET DESIGN
CONSTANTS
INPUT IN-PLACE
DENSITY OF
SUBGRADE
INPUT CBR OF
SUBGRADE AT
90-95% CE 55
IS
CBR
BETWEEN
2 & 50?
NO
YES
7

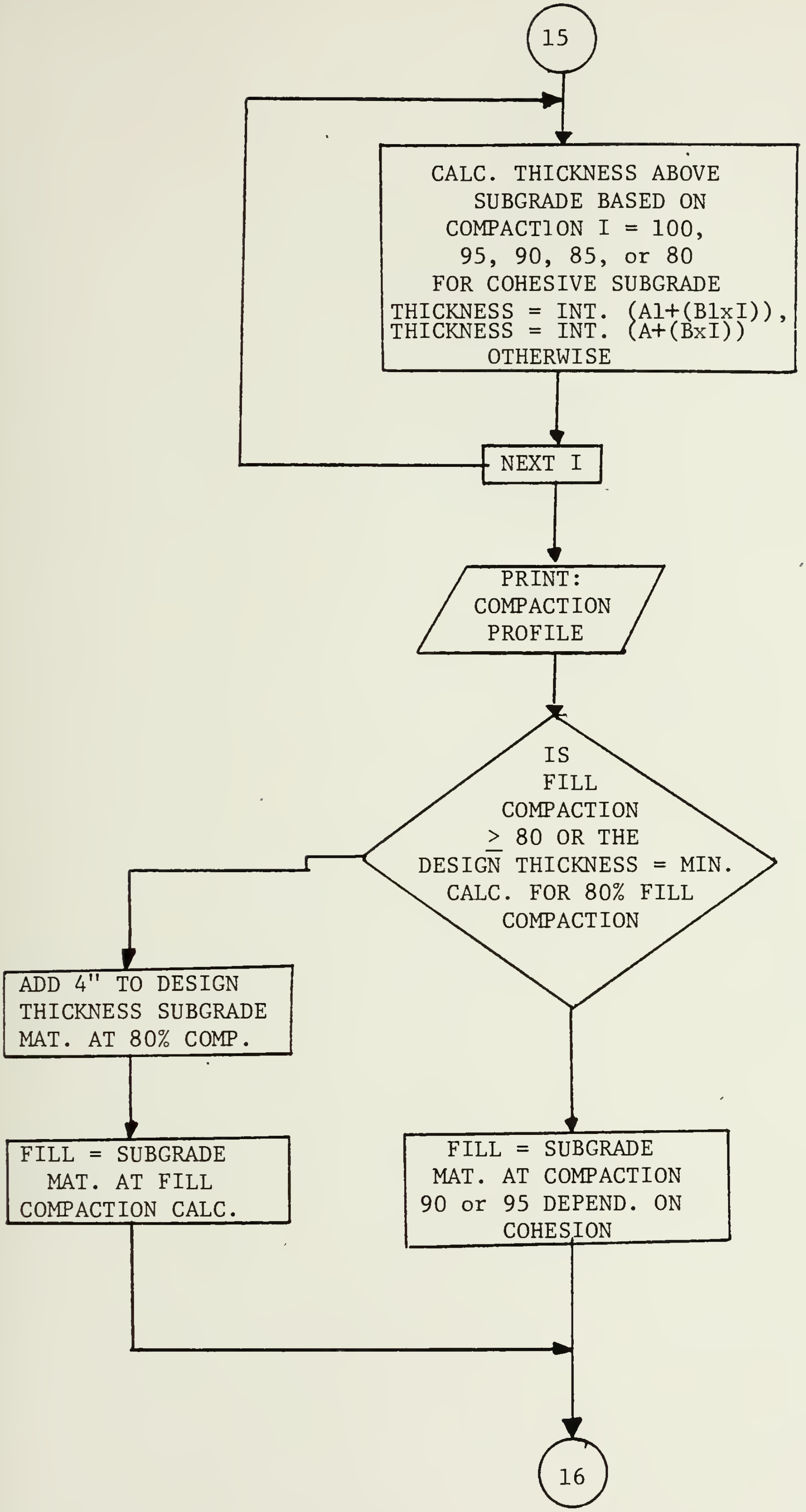

7
INPUT NO. OF BASE, SUBBASE AND SELECT MAT. TO TO BE CONSIDERED
IS THIS NUMBER LESS THAN 7?
NO
YES
INPUT CBR VALUE OF BASE COURSE
INPUT CBR OF REMAINING MAT. IN DESC. ORDER
IS CBR BETWEEN 0 AND 101
NO
YES
IS THE NO. OF MATERIALS LESS THAN 2
NO
YES
8
ARE THE MATERIALS GIVEN IN DESC. ORDER
NO
YES
IS CBR OF BASE GREATER THAN 100?
NO
9
IS CBR OF BASE GREATER THAN 80
YES
10
NO
11

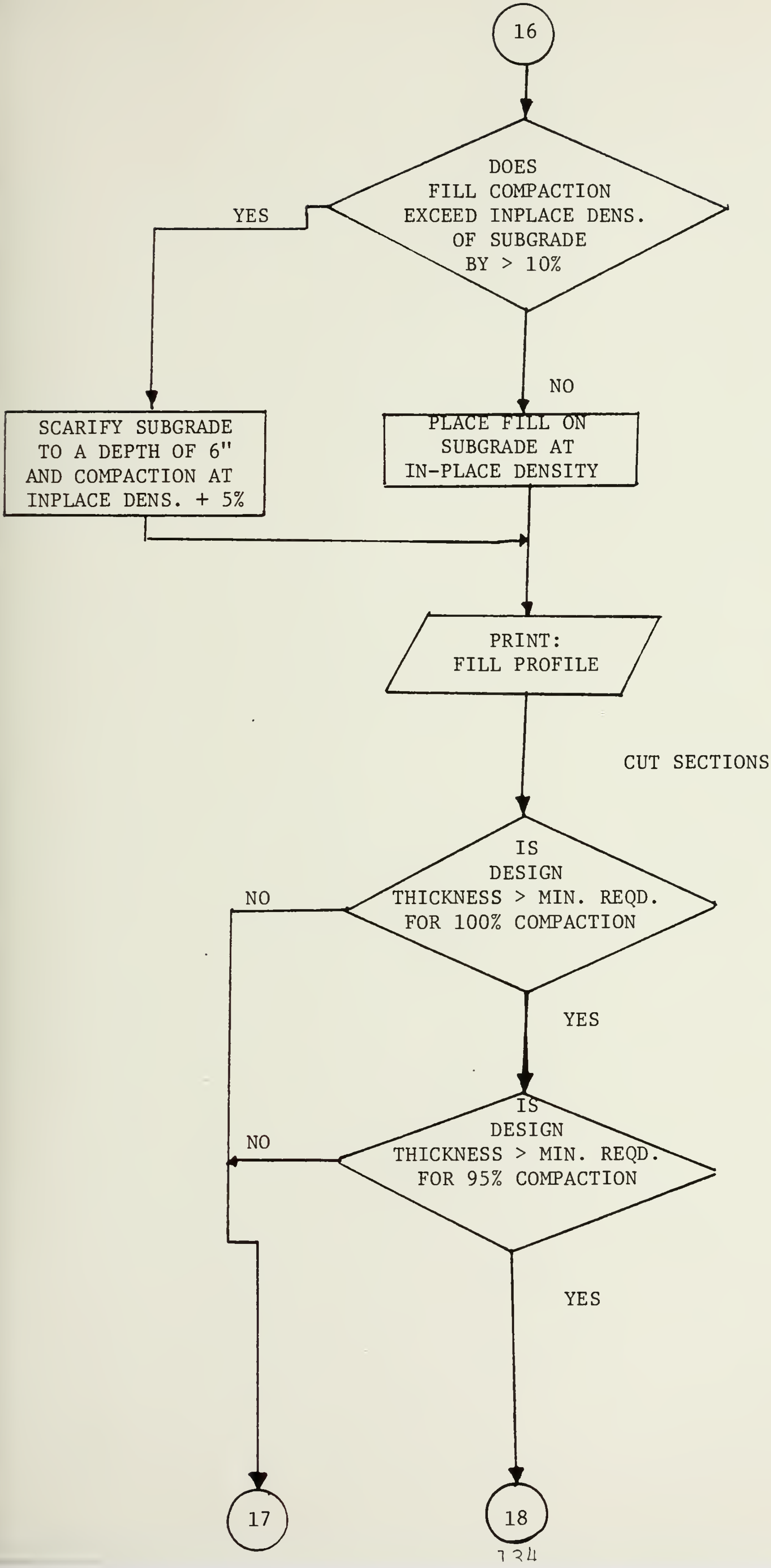

7
11
IS CBR OF BASE GREATER THAN 50?
NO
YES
9
10
READ DATA 3 (THICKNESSES OF SURFACE FOR DESIGN INDEXES)
READ DATA 1 (THICKNESSES OF SURFACE FOR DESIGN INDEXES)
READ DATA 2 (THICKNESSES OF SURFACE FOR DESIGN INDEXES)
8
CALCULATE COEFFICIENTS: A1, B1, A, & B
ESTABLISH ROAD CLASSIFICATION:
IS CBR OF MAT. OTHER THAN BASE ≥ 6? INCLUDES SUBGRADE
NO
YES
CALCULATE MIN. THICKNESS OF PVMT. ABOVE THIS MAT. (I)
TH=INT(1/(A1+(B1xCBR)))+0.5
CALCULATE MIN. THICKNESS OF PVMT. ABOVE THIS MAT. (I)
TH=INT(1/(A+(BxCBR)))+0.5
PRINT MIN. THICKNESS OF PAVEMENT ABOVE THIS MAT. (I)
NEXT I
12

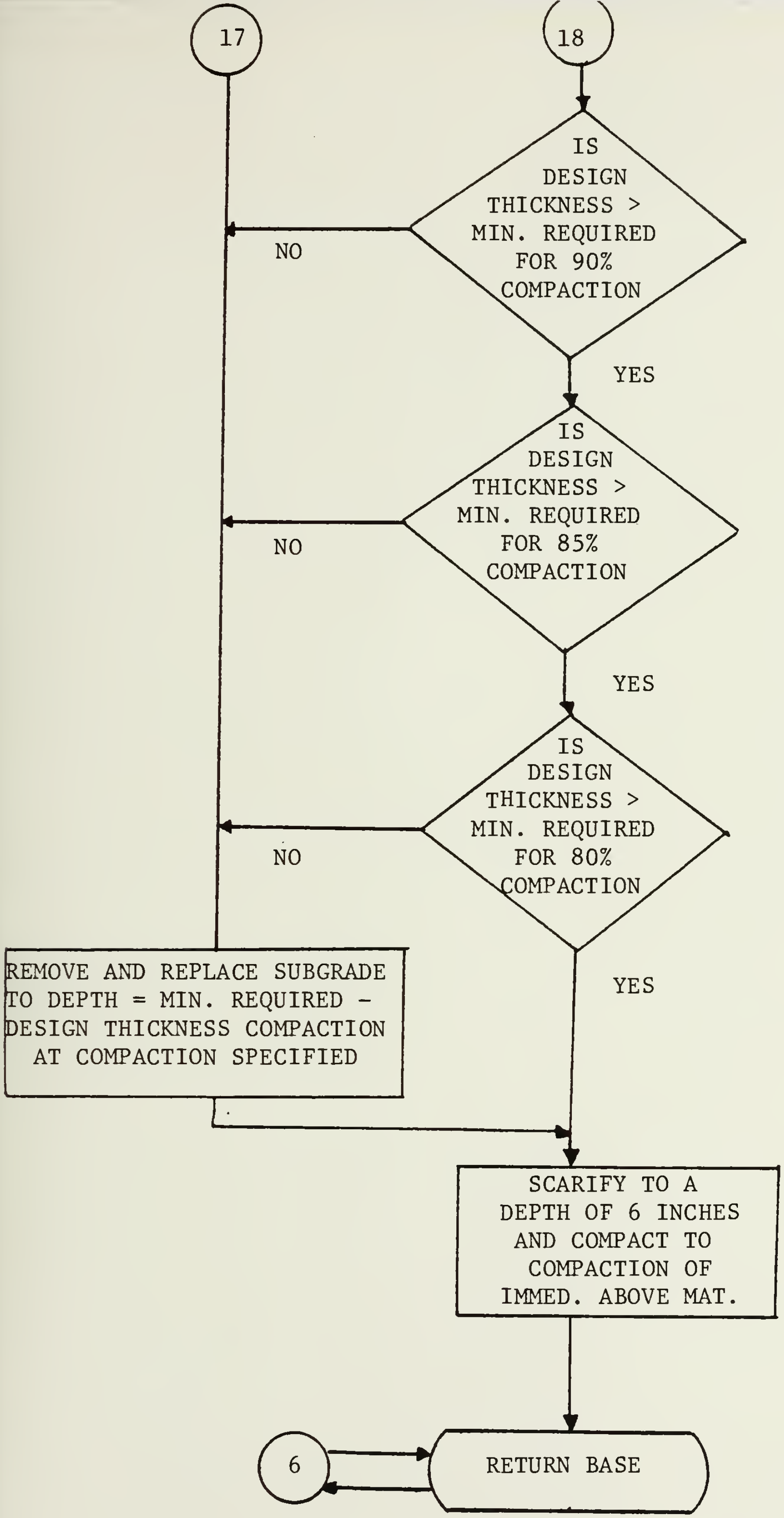

12
IS MIN. SURFACE THICK = 0.5 AND CBR BASE $\geq$ 80
YES
NO
IS MIN. SURF. THICK = 0.5 AND CBR BASE $\geq$ 100?
YES
PRINT: "BITUM. SURFACE TREATMENT REQUIRED" - MIN. BASE THICKNESS = 4 INCHES"
NO
PRINT: MULT. BITUM. SURFACE TREATMENT REQUIRED
YES
IS MIN. SURFACE THICK = 1.0?
NO
SET X = MIN. SURF. THICKNESS
SET Y = 4 INCHES (ABS. MIN. FOR BASE COURSE)
IS X + Y $\geq$ 6
YES
NO
SET BASE THICKNESS = 6-SURFACE THICKNESS
13

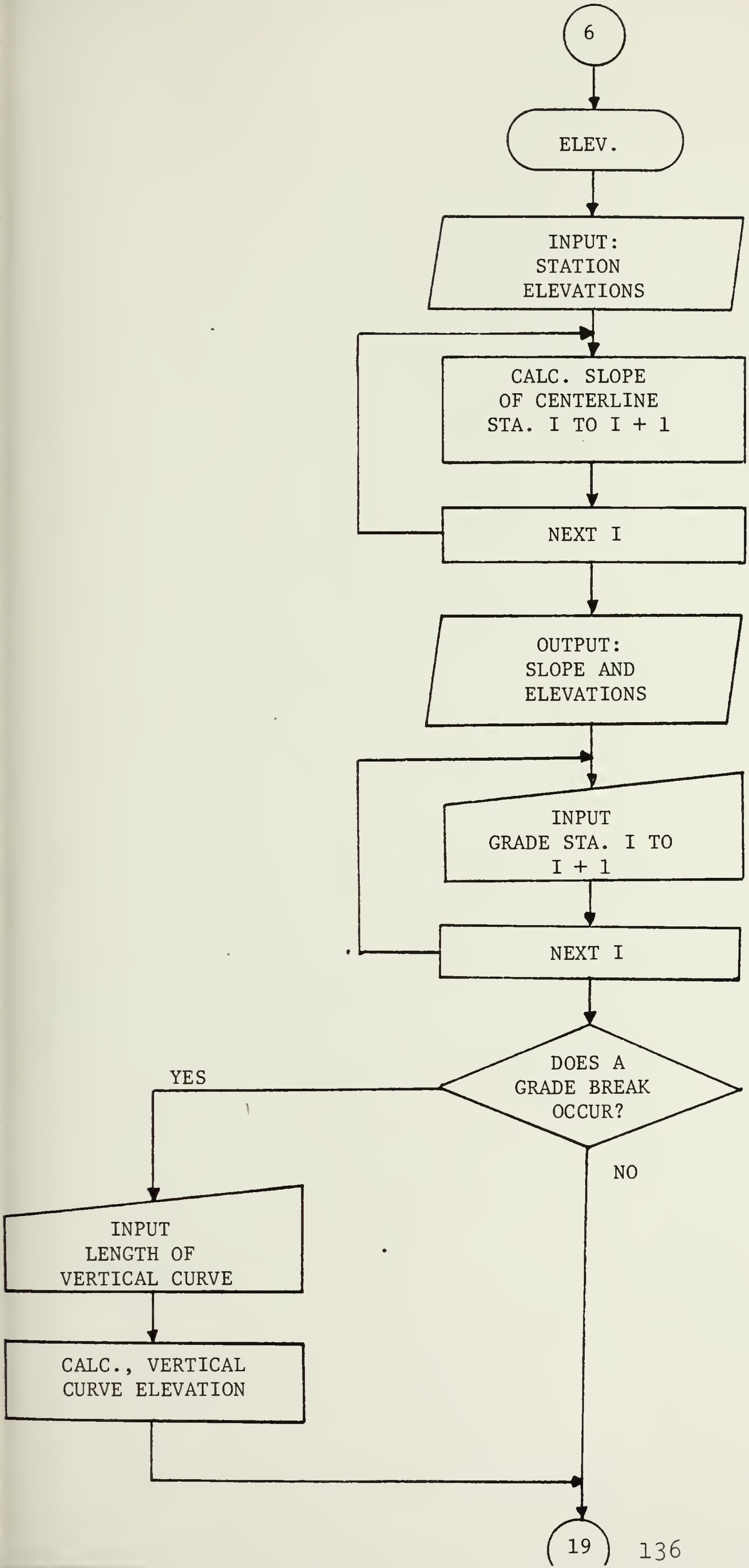

13
LET DESIGN THICKNESS THUS FAR = SURFACE THICKNESS + BASE THICKNESS
LET THICKNESS OF THIS MAT.(I) = MIN. THICKNESS ABOVE NEXT MAT. (I) - DESIGN THICKNESS THUS FAR
IS THICKNESS OF MAT. (I) ≥ 4
YES
NO
SET THICKNESS MAT(I) = 4
LET DESIGN THICKNESS THUS FAR = PREV. DESIGN THICKNESS + THICKNESS MAT. (I)
IS NEXT MATERIAL SUBGRADE ?
NEXT I
NO
YES
LET THICKNESS ABOVE SUBGRADE = DESIGN THICKNESS THUS FAR
14

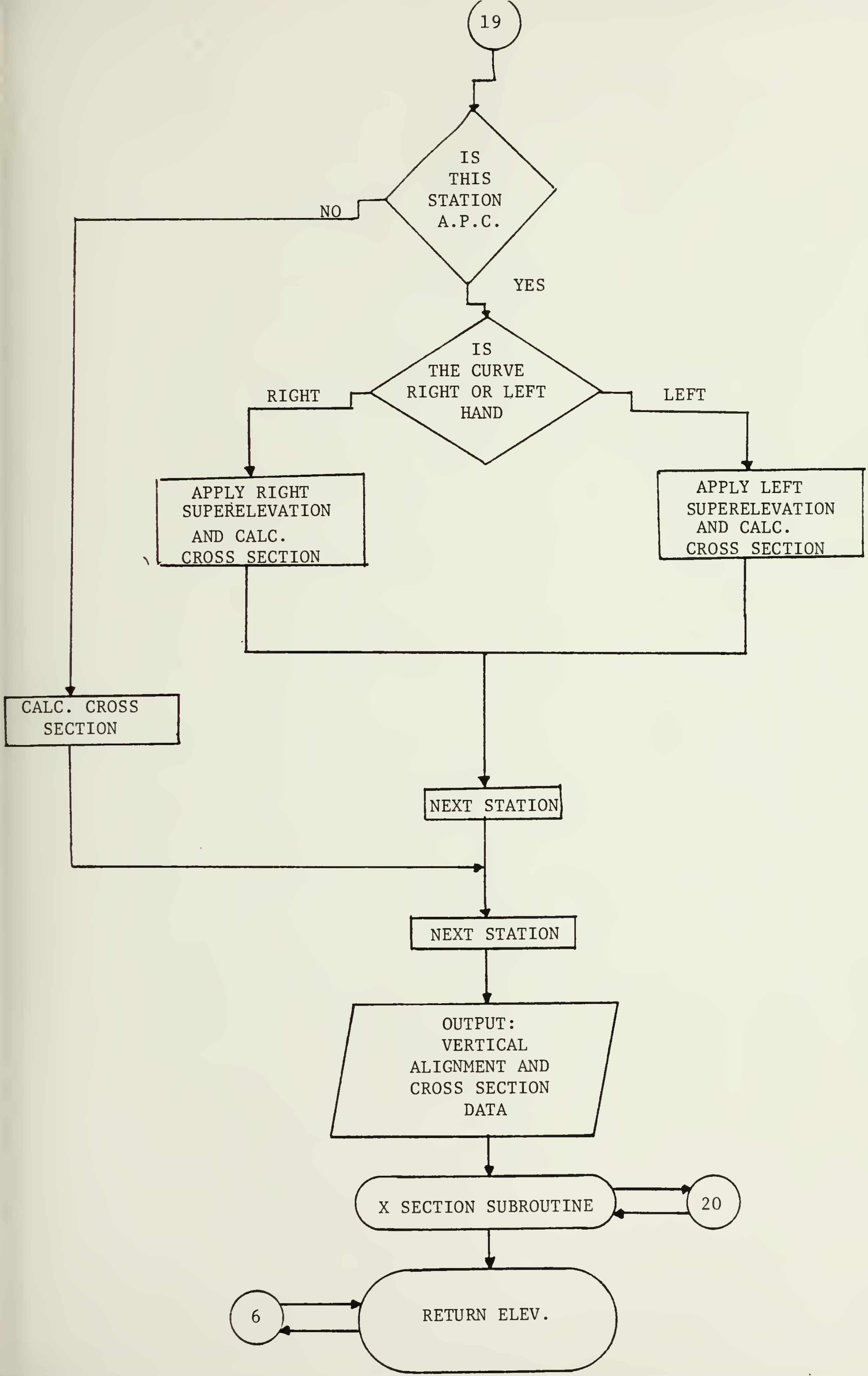

14
PRINT DESIGN PROFILE WITH CBR. OF MAT. THICKNESS OF MAT. CUM. THICKNESS SUBGRADE CBR
INPUT SUBGRADE COHESION INDICATOR
SET BASE COMPACT. = 100%
CALC. COEFF. FOR MIN. THICKNESS BASED ON COMPACTION
FOR MAT. BELOW BASE IS CBR OF MAT. (I) < 20?
YES
IS SUBGRADE COHESIVE
YES
NO
COMPACTION MAT.(I)=90%
COMPACTION MAT.(I)=100%
SET COMPACTION MAT.(I)=95%
NEXT I
15

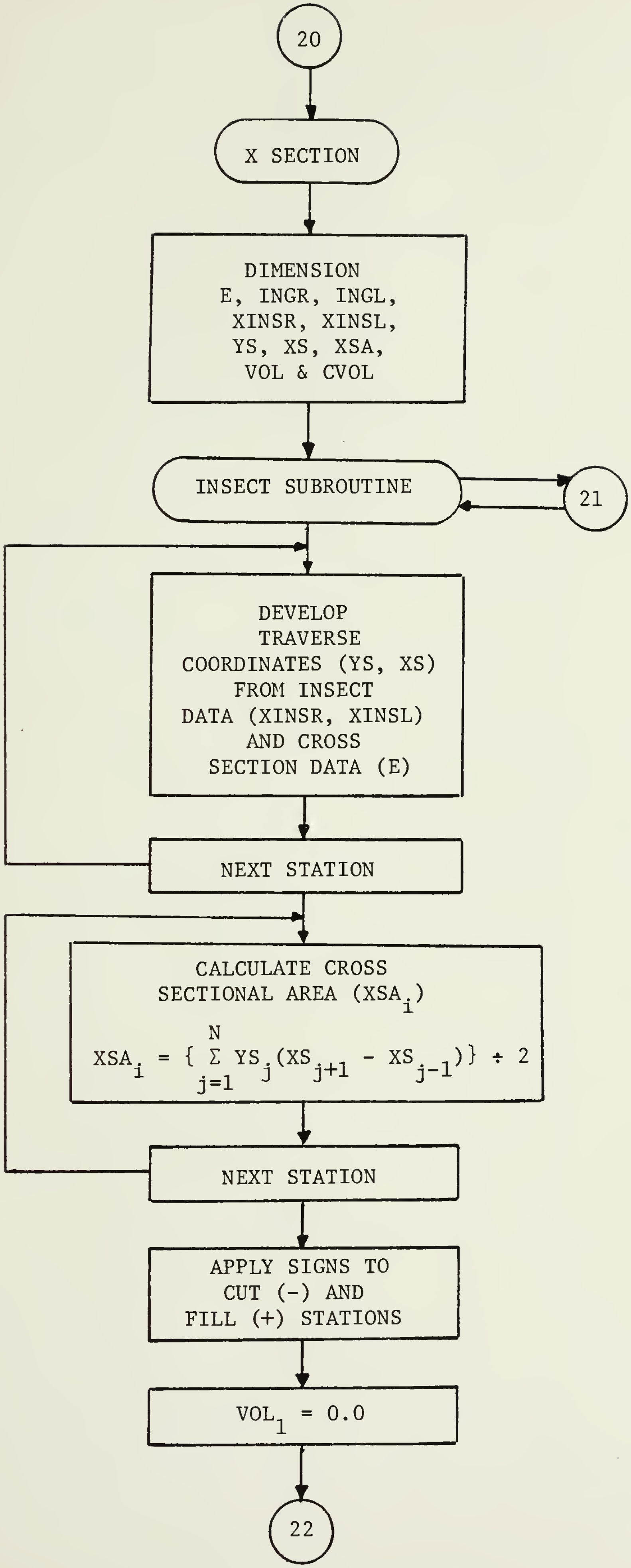

15
CALC. THICKNESS ABOVE SUBGRADE BASED ON COMPACTION I = 100, 95, 90, 85, or 80
FOR COHESIVE SUBGRADE THICKNESS = INT. (A1+(B1xI)),
THICKNESS = INT. (A+(BxI)) OTHERWISE
NEXT I
PRINT: COMPACTION PROFILE
IS FILL COMPACTION ≥ 80 OR THE DESIGN THICKNESS = MIN. CALC. FOR 80% FILL COMPACTION
ADD 4" TO DESIGN THICKNESS SUBGRADE MAT. AT 80% COMP.
FILL = SUBGRADE MAT. AT FILL COMPACTION CALC.
FILL = SUBGRADE MAT. AT COMPACTION 90 or 95 DEPEND. ON COHESION
16

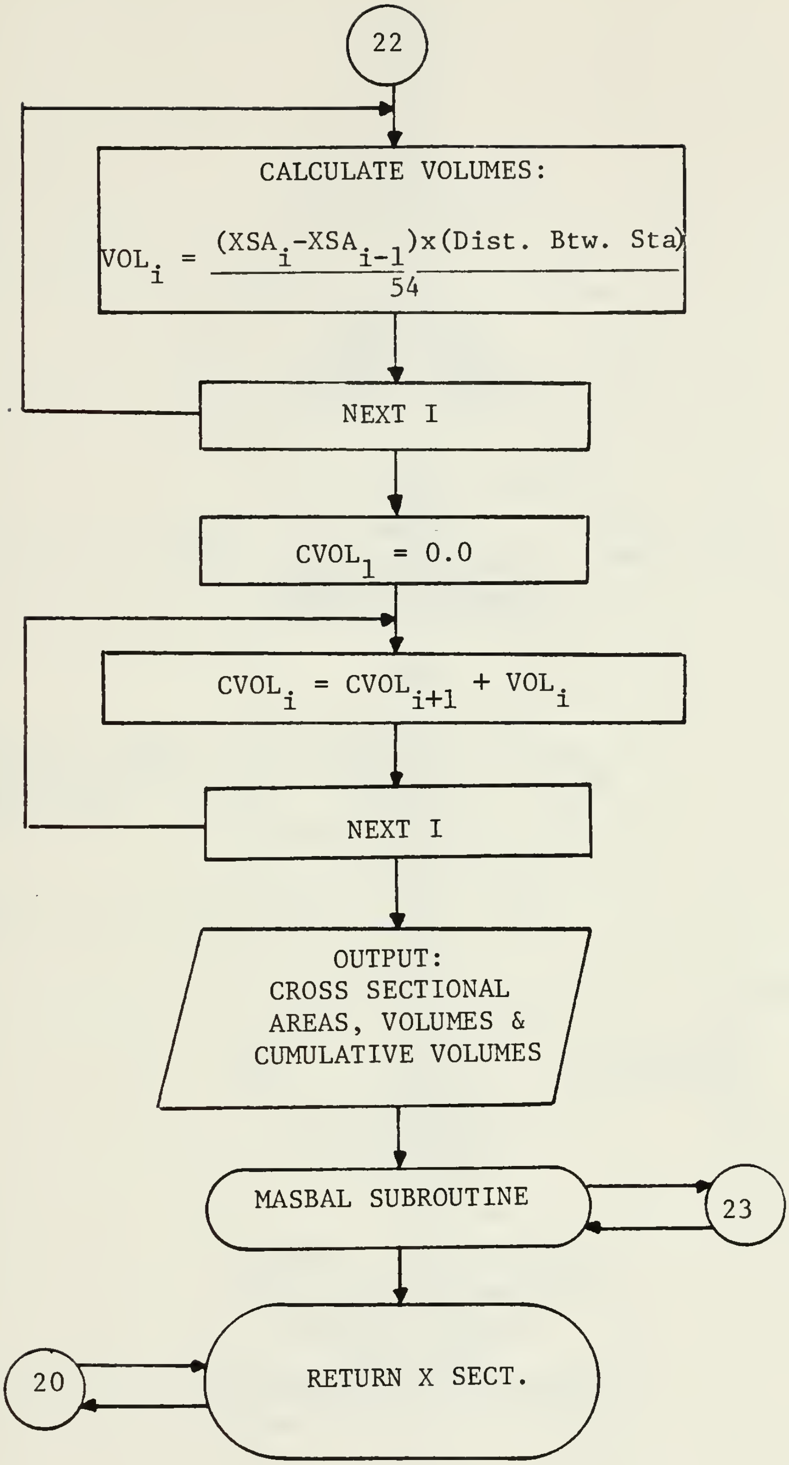

16
DOES FILL COMPACTION EXCEED INPLACE DENS. OF SUBGRADE BY > 10%
YES
NO
SCARIFY SUBGRADE TO A DEPTH OF 6" AND COMPACTION AT INPLACE DENS. + 5%
PLACE FILL ON SUBGRADE AT IN-PLACE DENSITY
PRINT: FILL PROFILE
CUT SECTIONS
IS DESIGN THICKNESS > MIN. REQD. FOR 100% COMPACTION
NO
YES
IS DESIGN THICKNESS > MIN. REQD. FOR 95% COMPACTION
NO
YES
17
18

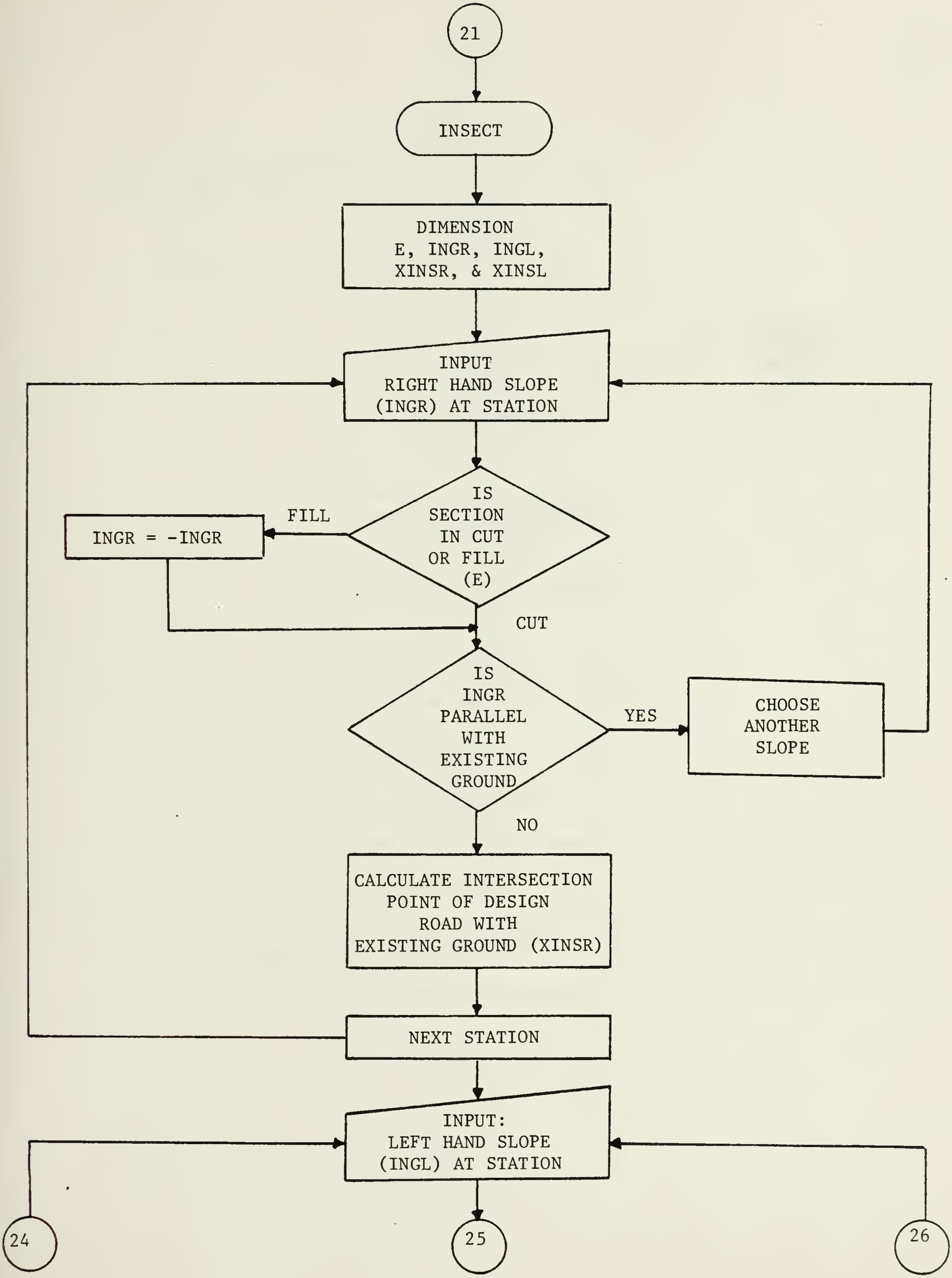

17
18
IS DESIGN THICKNESS > MIN. REQUIRED FOR 90% COMPACTION
NO
YES
IS DESIGN THICKNESS > MIN. REQUIRED FOR 85% COMPACTION
NO
YES
IS DESIGN THICKNESS > MIN. REQUIRED FOR 80% COMPACTION
NO
YES
REMOVE AND REPLACE SUBGRADE TO DEPTH = MIN. REQUIRED - DESIGN THICKNESS COMPACTION AT COMPACTION SPECIFIED
SCARIFY TO A DEPTH OF 6 INCHES AND COMPACT TO COMPACTION OF IMMED. ABOVE MAT.
6
RETURN BASE

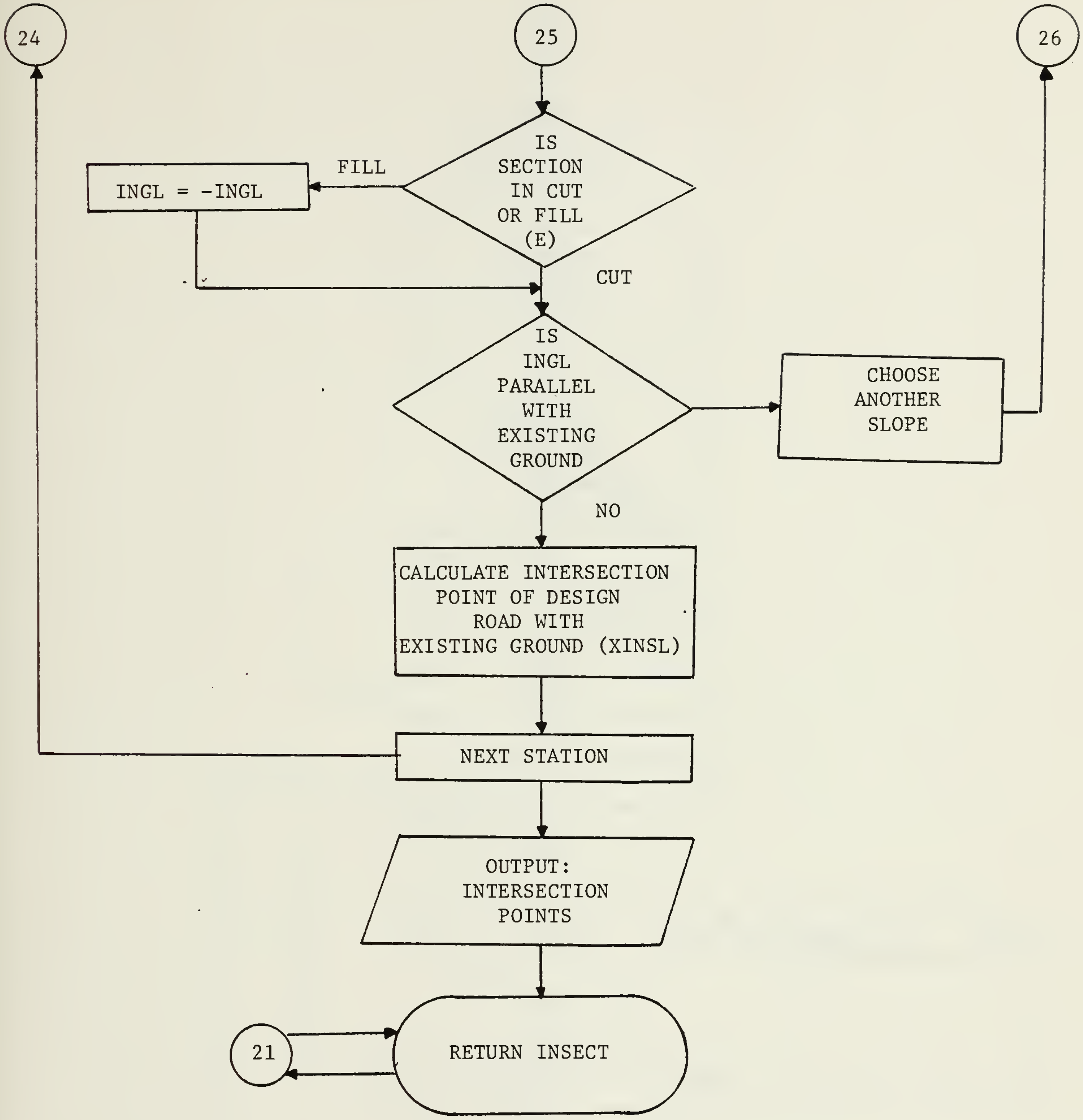

6
ELEV.
INPUT:
STATION
ELEVATIONS
CALC. SLOPE
OF CENTERLINE
STA. I TO I + 1
NEXT I
OUTPUT:
SLOPE AND
ELEVATIONS
INPUT
GRADE STA. I TO
I + 1
NEXT I
DOES A
GRADE BREAK
OCCUR?
YES
NO
INPUT
LENGTH OF
VERTICAL CURVE
CALC., VERTICAL
CURVE ELEVATION
19

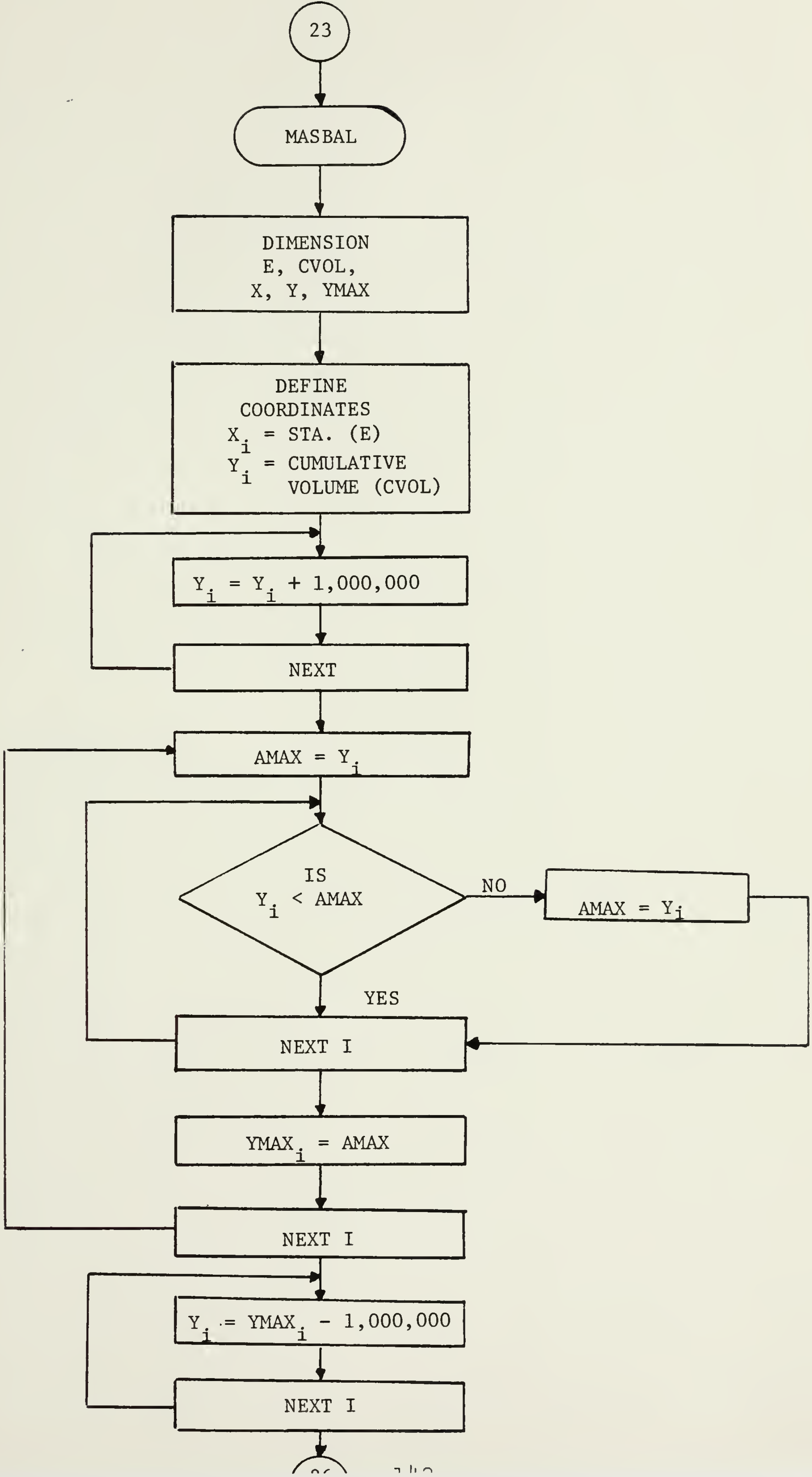

19
IS THIS STATION A.P.C.
NO
YES
IS THE CURVE RIGHT OR LEFT HAND
RIGHT
LEFT
APPLY RIGHT SUPERELEVATION AND CALC. CROSS SECTION
APPLY LEFT SUPERELEVATION AND CALC. CROSS SECTION
CALC. CROSS SECTION
NEXT STATION
NEXT STATION
OUTPUT: VERTICAL ALIGNMENT AND CROSS SECTION DATA
X SECTION SUBROUTINE
20
6
RETURN ELEV.

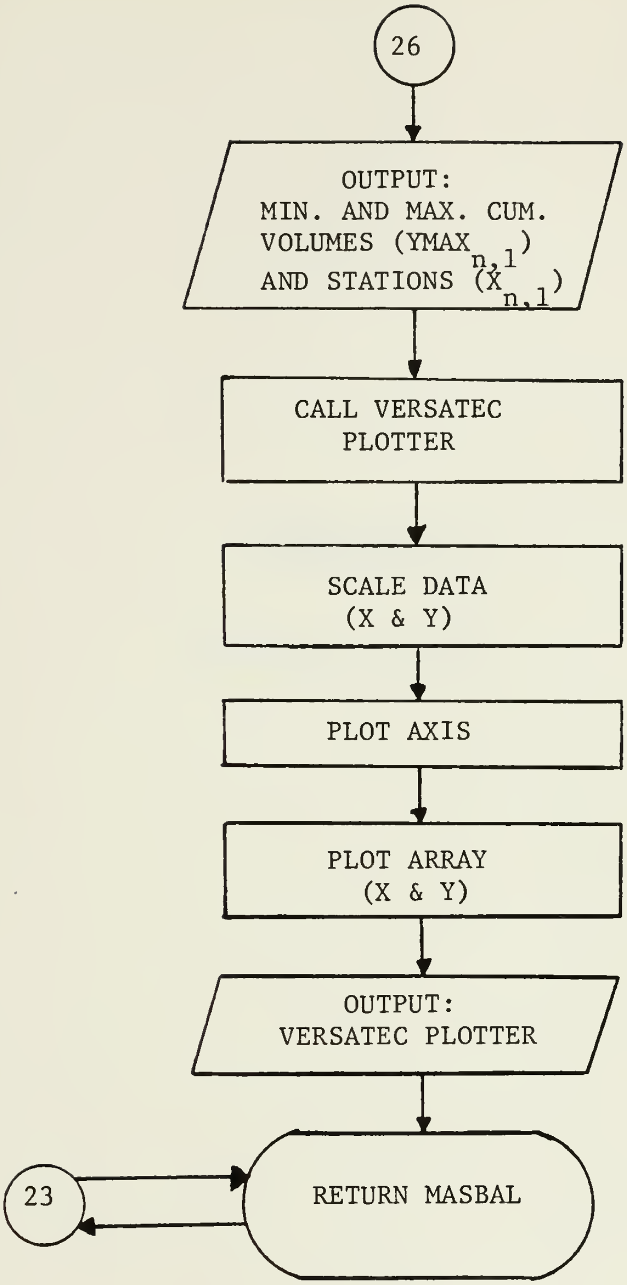

20
X SECTION
DIMENSION E, INGR, INGL, XINSR, XINSL, YS, XS, XSA, VOL & CVOL
INSECT SUBROUTINE
21
DEVELOP TRAVERSE COORDINATES (YS, XS) FROM INSECT DATA (XINSR, XINSL) AND CROSS SECTION DATA (E)
NEXT STATION
CALCULATE CROSS SECTIONAL AREA (XSA_i)
$XSA_i = \{ \sum_{j=1}^{N} YS_j (XS_{j+1} - XS_{j-1}) \} \div 2$
NEXT STATION
APPLY SIGNS TO CUT (-) AND FILL (+) STATIONS
$VOL_1 = 0.0$
22


22
CALCULATE VOLUMES:
$VOL_i = \frac{(XSA_i - XSA_{i-1}) \times (Dist.\ Btw.\ Sta)}{54}$
NEXT I
$CVOL_1 = 0.0$
$CVOL_i = CVOL_{i+1} + VOL_i$
NEXT I
OUTPUT:
CROSS SECTIONAL
AREAS, VOLUMES &
CUMULATIVE VOLUMES
MASBAL SUBROUTINE
23
RETURN X SECT.
20


21
INSECT
DIMENSION
E, INGR, INGL,
XINSR, & XINSL
INPUT
RIGHT HAND SLOPE
(INGR) AT STATION
IS
SECTION
IN CUT
OR FILL
(E)
FILL
INGR = -INGR
CUT
IS
INGR
PARALLEL
WITH
EXISTING
GROUND
YES
CHOOSE
ANOTHER
SLOPE
NO
CALCULATE INTERSECTION
POINT OF DESIGN
ROAD WITH
EXISTING GROUND (XINSR)
NEXT STATION
INPUT:
LEFT HAND SLOPE
(INGL) AT STATION
24
25
26


24
25
26
IS SECTION IN CUT OR FILL (E)
FILL
INGL = -INGL
CUT
IS INGL PARALLEL WITH EXISTING GROUND
CHOOSE ANOTHER SLOPE
NO
CALCULATE INTERSECTION POINT OF DESIGN ROAD WITH EXISTING GROUND (XINSL)
NEXT STATION
OUTPUT: INTERSECTION POINTS
RETURN INSECT
21


23
MASBAL
DIMENSION
E, CVOL,
X, Y, YMAX
DEFINE
COORDINATES
X_i = STA. (E)
Y_i = CUMULATIVE
VOLUME (CVOL)
$Y_i = Y_i + 1,000,000$
NEXT
AMAX = Y_i
IS
Y_i < AMAX
NO
AMAX = Y_i
YES
NEXT I
$YMAX_i$ = AMAX
NEXT I
$Y_i = YMAX_i - 1,000,000$
NEXT I


26
OUTPUT:
MIN. AND MAX. CUM.
VOLUMES ($YMAX_{n,1}$)
AND STATIONS ($X_{n,1}$)
CALL VERSATEC PLOTTER
SCALE DATA (X & Y)
PLOT AXIS
PLOT ARRAY (X & Y)
OUTPUT:
VERSATEC PLOTTER
23
RETURN MASBAL

APPENDIX E

PROGRAM LISTING

```
 OLD,FIRD
/ATTACH,CALCOMP/UN=LIBRARY
/LIBRARY(CALCOMP)
LIBRARY(CALCOMP)
/FTN,I=FIRD,R=0,TS
1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      1
     PROGRAM MAIN       73/74    TS

                     PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE9
   >>>>    )
           C         BEGIN FIRD, ROAD DESIGN PROGRAM MODELLED AFTER
           C         THE SPECIAL RESEARCH PROJECT OF R. SETZEKORN
           C
                     DIMENSION H(20,8),R(20,4)
                     DIMENSION S(10,6)
                     DIMENSION G(50),E(50,15)
                     INTEGER U
                     INTEGER V
                     INTEGER W
                     INTEGER D1
           C
           C         JCL COMMANDS
           C         OLD,FIRD
           C         ATTACH,CALCOMP/UN=LIBRARY
           C         LIBRARY(CALCOMP)
           C         FTN,I=FIRD,L=0,TS
           C         LGO
```

```
C      PLOTCV(TAPE9)
C
       WRITE(6,101)
101    FORMAT(///,14X,33("*")," ROAD DESIGN ",33("*"),///)
       WRITE(6,102)
102    FORMAT("THIS PROGRAM IS A SERIES OF SUBROUTINES DESIGNED
>>>>   ",/,
      C"TO ASSIST THE ENGINEER IN A MILITARY ROAD DESIGN.",/,
      C"THE OPERATION OF THE PROGRAM IS INTERACTIVE,",/,
      C"AND REQUIRES THE USE OF THE USERS MANUAL.",//)
       WRITE(6,103)
103    FORMAT(44X,"HORIZONTAL ALIGNMENT",//)
       WRITE(6,104)
104    FORMAT("ENTER NO. OF CURVES THIS SECTION")
       READ(5,105)N
105    FORMAT(I2)
       IF(N.EQ.0) GO TO 175
70     DO 106 I=1,N
75     WRITE(6,107)I
107    FORMAT(//,"ENTER STA NO OF TANGENT INTERSECTION OF CURVE
>>>>    ",I2)
       READ(5,108)H(I,1)
108    FORMAT(F7.3)
       WRITE(6,109)
109    FORMAT(//,"ENTER ANGLE OF INTERSECTION OF CURVE IN DEGRE
>>>>   ES")
       READ(5,110)A
110    FORMAT(F7.3)
       X=(A*6.28318)/360.
       WRITE(6,111)
111    FORMAT(//,"ENTER CHORD LENGTH IN FEET")
       READ(6,112)C
112    FORMAT(F7.3)
       WRITE(6,113)
```

```
   113   FORMAT(//)
         H(I,2)=C/(2.*SIN(X/2.))
         H(I,3)=A*H(I,2)*3.1416/180.
         H(I,4)=5729.28/H(I,3)
1 FTN 4.8+528        81/11/03. 09.30.59 PAGE      2
   PROGRAM MAIN      73/74    TS

         H(I,5)=H(I,2)*TAN(X/2.)
         H(I,6)=H(I,1)-(H(I,5)/100.)
         H(I,7)=H(I,1)+(H(I,3)/100.)
         H(I,1)=H(I,6)+(H(I,3)/200.)
         IF(H(I,4).GT.10.) GO TO 135
   106   CONTINUE
         GO TO 145
   135   WRITE(6,114)
   114   FORMAT("WARNING D TOO HIGH REESTABLISH PC, PT, ANDC",//)
         GO TO 75
   145   WRITE(6,115)
   115   FORMAT(T10,"STA NO.",T21,"RAD",T30,"L OF C",T45,"D OF C"
>>>>   ,T60,"TAN
        CLEN",T70,"PC STA",T80,"PT STA",/)
         DO 116 I=1,N
         WRITE(6,117)H(I,1),H(I,2),H(I,3),H(I,4),H(I,5),H(I,6),H(
>>>>   I,7)
   117   FORMAT(T9,F7.3,T20,F7.2,T30,F7.3,T45,F7.5,T60,F7.3,T70,F
>>>>   7.3,T80,F7
        C.3)
   116   CONTINUE
         U=N
         GO TO 205
   C     SUBROUTINE 1400
   175   CALL  BASE (S,N)
   C     SUBROUTINE 4000
```

```
180   CALL  ELEV(E,G)
      WRITE(6,120)
120   FORMAT("THIS PROGRAM WILL END")
      GO TO 9999
205   WRITE(6,121)
121   FORMAT(///,37X," SUPERELEVATION SUPERL")
      DO 122 I=1,N
220   WRITE(6,123)I
123   FORMAT(//,"WHAT IS DESIGN VELOCITY OF CURVE ",I2)
      READ(5,124)V
124   FORMAT(I2)
      IF(V.EQ.30) GO TO 260
      IF(V.EQ.40) GO TO 270
      IF(V.EQ.50) GO TO 280
      IF(V.EQ.60) GO TO 290
      WRITE(6,125)
125   FORMAT(//,"INVALID VELOCITY-TRY AGAIN")
      GO TO 220
260   F=0.16
      GO TO 295
270   F=0.1
      GO TO 295
280   F=0.14
      GO TO 295
290   F=0.13
295   X=V
      H(I,8)=(X**2/(15.*H(I,2)))-F
```

```
                  IF(H(I,8).LE.0.) GO TO 350
                  IF(H(I,8).LE.0.08) GO TO 122
                  IF(H(I,8).LE.0.10) GO TO 325
                  WRITE(6,126)I
 1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      3
     PROGRAM MAIN       73/74    TS

             126  FORMAT(//,"WARNING-RADIUS MUST INCREASE TO DECREASE SUPE
  >>>>       RL OF CURV
                 CE",I2)
                  GO TO 135
             325  WRITE(6,127)
             127  FORMAT("WARNING-IS SNOW PREVALENT?",/,
                 C"ENTER 1 IF YES AND 2 IF NO.",/,
                 C/)
                  READ(5,128)W
             128  FORMAT(I1)
                  IF(W.EQ.1) GO TO 70
                  IF(W.EQ.2) GO TO 122
             350  H(I,8)=0.
             122  CONTINUE
                  WRITE(6,129)
             129  FORMAT(T10,"STA NO",T21,"RAD",T30,"L OF C",T45,"SUPERL",
  >>>>       T60,"TAN L
                 CEN",T70,"PC STA",T80,"PT STA",/)
                  DO 130 I=1,N
                  WRITE(6,131)H(I,1),H(I,2),H(I,3),H(I,8),H(I,5),H(I,6),H(
  >>>>       I,7)
             131  FORMAT(T9,F7.3,T21,F7.2,T30,F7.3,T43,F10.8,T60,F7.3,T70,
  >>>>       F7.3,T80,F
                 C7.3)
             130  CONTINUE
                  GO TO 175
            9999  JOE=1
                  END

   42000B CM STORAGE USED          1.225 SECONDS
 1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      1
```

```
      C
      C        SUBROUTINE 1400
      C
               SUBROUTINE BASE(S,N)
               DIMENSION S(10,6),R(20,4)
               INTEGER D1
               WRITE(6,132)
      132      FORMAT(//)
               DO 133 I=1,6
               DO 134 J=1,10
               S(J,I)=0.
      134      CONTINUE
      133      CONTINUE
               WRITE(6,141)
      141      FORMAT("WHAT DESIGN INDEX IS TO BE USED?")
               READ(5,136)D1
      136      FORMAT(I1)
      1445     WRITE(6,137)
      137      FORMAT("WHAT IS THE IN-PLACE (%CE55) OF THE SUBGRADE?")
               READ(5,138)ABCS
      138      FORMAT(F4.1)
               S(10,2)=ABCS
               IF(S(10,2).LT.20.) GO TO 1460
               IF(S(10,2).GT.100.) GO TO 1460
               GO TO 1470
      1460     WRITE(6,139)
      139      FORMAT("INPLACE DENSITY MUST BE GIVEN AS %CE55. TRY AGAI
 >>>> N.")
               GO TO 1445
      1470     WRITE(6,9941)
      9941     FORMAT("WHAT IS THE CBR OF THE SUBGRADE AT 90% TO 95% CE
 >>>> 55?")
```

```
              READ(5,140)BCDS
        140   FORMAT(F4.1)
              S(10,1)=BCDS
              IF(S(10,1).LT.1.) GO TO 1485
              IF(S(10,1).GT.100.) GO TO 1485
              GO TO 1495
        1485  WRITE(6,1000)
        1000  FORMAT("VALUES FOR CBR SHOULD RANGE FROM ABOUT 2 TO 50.
  >>>>  TRY AGAIN.
             C")
              GO TO 1470
        1495  WRITE(6,1001)
        1001  FORMAT("HOW MANY TYPES OF BASE, SUBBASE, AND SELECT MATE
  >>>>  RIALS",/,
             C"DO YOU WISH TO CONSIDER?( DO NOT INCLUDE SUBGRADE OR PA
  >>>>  VT)")
              READ(5,1002)L
        1002  FORMAT(I1)
              IF(L.EQ.0) GO TO 1515
              IF(L.GT.7) GO TO 1515
              GO TO 1530
        1515  WRITE(6,1003)
        1003  FORMAT("THIS PROGRAM WILL HANDLE UP TO 7 DIFFERENT SOILS
  >>>>  .",/,
             C"THIS SHOULD BE MORE THAN SUFFICIENT.")
1 FTN 4.8+528         81/11/03. 09.30.59 PAGE      2
  SUBROUTINE BASE      73/74   TS

              GO TO 1495
        1530  WRITE(6,1004)
        1004  FORMAT("WHAT IS THE CBR VALUE OF THE BASE COURSE?")
              READ(5,1005)CDES
```

```
 1005  FORMAT(F4.1)
       S(2,1)=CDES
       LCUCH=L+1
       DO 1006 I=3,LCUCH
 1545  WRITE(6,1007)
 1007  FORMAT("WHAT IS THE NEXT HIGHEST CBR?")
       READ(5,1008)DEFS
 1008  FORMAT(F5.1)
       S(I,1)=DEFS
       IF(S(I,1).LE.0.) GO TO 1560
       IF(S(I,1).GE.101.) GO TO 1560
       GO TO 1006
 1560  WRITE(6,1010)
 1010  FORMAT("VALUES FOR CBR SHOULD RANGE FROM ABOUT 2 TO 100.
>>>>   ",/,
      C"TRY AGAIN.")
       GO TO 1545
 1006  CONTINUE
       IF(L.LT.2) GO TO 1665
       DO 1011 I=2,LCUCH
       IF(S(I+1,1).LE.S(I,1)) GO TO 1011
       WRITE(6,1012)
 1012  FORMAT("CBR VALUES WERE NOT GIVEN IN DESCENDING ORDER.",
>>>>   /,
       C"TRY AGAIN.")
```

```
           GO TO 1530
      1011 CONTINUE
           IF(S(2,1).GE.100.) GO TO 1630
           IF(S(2,1).GE.80.) GO TO 1640
           IF(S(2,1).GE.50.) GO TO 1645
           WRITE(6,1013)
      1013 FORMAT("CBR OF BASE COURSE MUST BE ABOVE 50. TRY AGAIN."
>>>>     )
           GO TO 1530
      1630 S(1,6)=0.5
           S(2,6)=1.0
           S(3,6)=1.5
           S(4,6)=1.5
           S(5,6)-2.0
           S(6,6)=2.5
           S(7,6)=2.5
           S(8,6)=3.0
           S(9,6)=3.5
           S(10,6)=3.5
           GO TO 1665
      1640 S(1,6)=0.5
           S(2,6)=1.5
           S(3,6)=1.5
           S(4.6)=2.0
           S(5,6)=2.5
           S(6,6)=3.0
           S(7.6)=3.0
           S(8,6)=3.5
1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      3
  SUBROUTINE BASE      73/74    TS

           S(9,6)=3.5
           S(10,6)=4.0
           GO TO 1665
      1645 S(1,6)=2.0
           S(2,6)=2.5
```

```
      S(3,6)=2.5
      S(4,6)=3.0
      S(5,6)=3.5
      S(6,6)=4.0
      S(7,6)=4.5
      S(8,6)=5.0
      S(9,6)=5.5
      S(10,6)=6.0
 1665 A=1./(26.7561+4.90148*D1)
      A1=1./(33.4189+6.9253*D1)
      B=1./(73.9301+16.9388*D1)
      B1=1./(66.5998+14.6764*D1)
      WRITE(6,1681)
 1681 FORMAT("WHAT CLASSIFICATION IS TO BE USED?",/,
     C"A=1,B=2,C=3,D=4,E=5,F=6")
      READ(5,1683)C2
 1683 FORMAT(I1)
      WRITE(6,1690)
 1690 FORMAT(//)
      DO 1730 I=1,8
      J=11-I
      IF(S(J,1).EQ.0.) GO TO 1730
      IF(S(J,1).GT.6.) GO TO 1720
      IAA=(1./(A1+B1*S(J,1))+0.5)
      S(J,3)=IAA
      GO TO 1725
 1720 IBB=(1./(A+B*S(J,1))+0.5)
      S(J,3)=IBB
 1725 WRITE(6,1726)S(J,1),S(J,3)
 1726 FORMAT("MIN THICKNESS RQD ABOVE SOIL WITH CBR=",F4.1," I
>>>> S ",F4.1)
 1730 CONTINUE
      IF(S(D1,6).EQ.0.5.AND.S(2,1).EQ.80.) GO TO 1770
      IF(S(D1,6).EQ.0.5.AND.S(2,1).EQ.100.) GO TO 1780
      IF(S(D1,6).EQ.1.) GO TO 1770
      S(1,5)=S(D1,6)
```

```
                S(2,5)=4.0
                WRITE(6,1760)S(1,5)
         1760   FORMAT("THE MIN RQD THICKNESS OF PAVT IS",F4.1)
                GO TO 1785
         1770   WRITE(6,1771)
         1771   FORMAT("MULTIPLE BITUMINOUS SURFACE TREATMENT IS REQUIRE
  >>>>   D")
                GO TO 1785
         1780   WRITE(6,1781)
         1781   FORMAT("BITUMINOUS SURFACE TREATMENT IS REQUIRED")
         1785   WRITE(6,1786)
         1786   FORMAT("MIN RQD THICKNESS OF BASE COURSE IS 4 INCHES")
                ACUCH=S(1,5)+S(2,5)
                IF(ACUCH.GE.6.0.OR.C2.GT.4.0) GO TO 1815
                S(2,5)=6.0-S(D1,6)
                WRITE(6,1800)S(2,5)
1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      4
  SUBROUTINE BASE      73/74    TS

         1800   FORMAT("MIN TOTAL THICKNESS OF PAVT PLUS BASE COURSE FOR
  >>>>    ",/,
               C"CLASS C ROADS IS 6 INCHES. BASE COURSE WILL BE INCREASE
  >>>>   D",/,
               C"TO",F4.1,"INCHES")
         1815   S(2,4)=S(1,5)
                S5=S(1,5)+S(2,5)
                DO 1890 I=3,10
                JCUCH=I+1
                IF(JCUCH.EQ.11) GO TO 1840
                DO 1840 J=JCUCH,10
                IF(S(J,3).GT.0.0.OR.S(J,3).LT.0.0) GO TO 1860
         1840   CONTINUE
                IF(S5.GE.S(I,3)) GO TO 1860
                S5=S(I,3)
                S(I-1,5)=S(I,3)-S(I-1,4)
```

```
1860  S(I,5)=S(J,3)-S5
      IF(S(I,5).GE.4.0) GO TO 1875
      S(I,5)=4.0
1875  S(I,4)=S5
      S5=S5+S(I,5)
      IF(J.EQ.10) GO TO 1895
1890  CONTINUE
1895  S(10,4)=S5
      WRITE(6,1905)
1905  FORMAT(60("*"),/)
      WRITE(6,1915)
1915  FORMAT(22X,"DESIGN PROFILE",/,
     C" DEPTH",/,
     C"(INCHES)",/,
     C4X,"0",12X,7("="),1X,"TOP OF PAVEMENT",1X,7("="))
      DO 2080 I=1,9
      IF(S(I,5).EQ.0.0) GO TO 2085
      L=(S(I,5)*0.5)
      DO 1960 J=1,L
      WRITE(6,1955)
1955  FORMAT(/)
1960  CONTINUE
      IF(I.GT.3) GO TO 2020
      IF(I.EQ.1) GO TO 1975
      IF(I.EQ.2) GO TO 2000
      IF(I.EQ.3) GO TO 2010
1975  IF(S(I,5).GT.1.) GO TO 1990
      IF(I.GT.1) GO TO 2040
      WRITE(6,8500)S(I,5)
8500  FORMAT(T16,F4.1," INCHES:, SURFACE TREATMENT")
      GO TO 2045
2040  WRITE(6,2041)S(I,5),S(I,1)
2041  FORMAT(T16,F4.1,"INCHES: SURFACE TREATMENT",T55,"CBR=",F
>>>>  4.1)
      GO TO 2045
1990  IF(I.GT.1) GO TO 8541
```

```
           WRITE(6,8501)S(I,5)
     8501  FORMAT(T16,F4.1," INCHES OF ASPHALTIC PAVEMENT")
           GO TO 2045
     8541  WRITE(6,8502)S(I,5),S(I,1)
     8502  FORMAT(T16,F4.1," INCHES OF ASPHALTIC PAVEMENT",T55,"CBR
1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      5
  SUBROUTINE BASE      73/74   TS

  >>>>     =",F4.1)
           GO TO 2045
     2000  IF(I.GT.1) GO TO 8542
           WRITE(6,8503)S(I,5)
     8503  FORMAT(T16,F4.1," INCHES OF BASE COURSE")
           GO TO 2045
     8542  WRITE(6,8504)S(I,5),S(I,1)
     8504  FORMAT(T16,F4.1," INCHES OF BASE COURSE",T55,"CBR=",F4.1
  >>>>     )
           GO TO 2045
     2010  IF(I.GT.1) GO TO 8543
           WRITE(6,8505)S(I,5)
     8505  FORMAT(T16,F4.1," INCHES OF SUBBASE MATERIAL")
           GO TO 2045
     8543  WRITE(6,8506)S(I,5),S(I,1)
     8506  FORMAT(T16,F4.1," INCHES OF SUBBASE MATERIAL",T55,"CBR="
  >>>>     ,F4.1)
           GO TO 2045
     2020  IF(I.GT.1) GO TO 8544
           WRITE(6,8507)S(I,5)
     8507  FORMAT(T16,F4.1," INCHES OF SELECT MATERIAL")
```

```
           GO TO 2045
      8544 WRITE(6,8508)S(I,5),S(I,1)
      8508 FORMAT(T16,F4.1," INCHES OF SELECT MATERIAL",T55,"CBR=",
>>>>  F4.1)
      2045 DO 2055 J=1,L
           WRITE(6,2050)
      2050 FORMAT(/)
      2055 CONTINUE
           K=I+1
           IF(S(K,4).GT.0.0.OR.S(K,4).LT.0.0) GO TO 2075
           K=10
      2075 WRITE(6,2076)S(K,4)
      2076 FORMAT(T2,F4.1,T12,36("-"))
      2080 CONTINUE
      2085 WRITE(6,2086)S(10,1)
      2086 FORMAT(T22,"SUBGRADE",T55,"CBR=",F4.1,/,
          C60("*"))
           DO 2115 J=1,4
           DO 2110 I=1,10
           R(I,J)=0.0
      2110 CONTINUE
      2115 CONTINUE
      2119 WRITE(6,2120)
      2120 FORMAT("IF THE SUBGRADE IS COHESIVE(PI>5),TYPE 3",/,
          C"IF THE SUBGRADE IS NON-COHESIVE,TYPE 4.")
           READ(5,2130)K
      2130 FORMAT(I1)
           IF(K.EQ.3.OR.K.EQ.4) GO TO 2150
```

```
              WRITE(6,2140)
        2140  FORMAT("YOU MISUNDERSTOOD YOUR OPTIONS. TRY AGAIN.")
              GO TO 2119
        2150  R(2,1)=S(2,4)+S(2,5)
              R(2,2)=100.
              A1=70.7932+14.3841*D1
              B1=-0.677999-0.136691*D1
              A2=119.487+25.3872*D1
1 FTN 4.8+528         81/11/03. 09.30.59 PAGE      6
  SUBROUTINE BASE      73/74   TS

              B2=-1.13-0.240128*D1
              DO 2230 I=3,10
              IF(S(I,1).EQ.0.0) GO TO 2230
              R(I,1)=S(I,4)+S(I,5)
              IF(S(I,1).LT.20.) GO TO 2210
              R(I,2)=100.
              GO TO 2230
        2210  IF(K.EQ.4) GO TO 2225
              R(I,2)=90.
              GO TO 2230
        2225  R(I,2)=95.
        2230  CONTINUE
              J=0
              DO 2260 ICC=1,4
              I=100-(5*ICC)
              J=J+1
              IDD=(A1+B1*I)+0.5
              R(J,3)=IDD
              IEE=(A2+B2*I)+0.5
              R(J,4)=IEE
        2260  CONTINUE
              WRITE(6,2265)
        2265  FORMAT(60("*"),/,
```

```
      C9X,"COMPACTION REQUIREMENTS (WRITTEN)",/)
       WRITE(6,2280)
 2280  FORMAT("DEPTH",/,
      C"(INCHES)",7X,7("="),"  TOP OF PAVEMENT ",7("="))
       P=0.
       DO 2365 I-2,9
       IF(R(I,1).EQ.0.) GO TO 2370
       L=(R(I,1)-P)/2.-1.
       DO 2320 J=1,L
       WRITE(6,2315)
 2315  FORMAT(/)
 2320  CONTINUE
       WRITE(6,2325)R(I,2),S(I,1)
 2325  FORMAT(T15,F5.1,"% CBR=",F4.1)
       ZCUCH=L
       P=P+ZCUCH+1.
       L=R(I,1)-P-1.
       DO 2350 J=1,L
       WRITE(6,2345)
 2345  FORMAT(/)
 2350  CONTINUE
       WRITE(6,2355)R(I,1)
 2355  FORMAT(T3,F4.1,T10,36("-"))
       ZAA=L
       P=P+ZAA+1.
 2365  CONTINUE
 2370  WRITE(6,2371)R(10,2),S(10,1)
 2371  FORMAT(T15,F5.1,"% CBR=",F4.1,/,
      CT15,"T0F (TO DEPTH OF FILL)",//,
      C60("*"),/,T21,"FINAL DESIGN",/,
      CT19,"FOR FILL SECTIONS")
 C
 C     SUBROUTINE 2660
       CALL  FILLCUT(S,R,N,J1,K)
```

```
                ZDD=J1
                J=21.-ZDD*0.2
                IF(R(10,2).GE.J1.OR.R(6,3).EQ.R(J,K)) GO TO 2430
                T=R(6,3)+4.
                WRITE(6,2420)S(10,1),J1
          2420  FORMAT(T11,"4 INCHES,CBR=",F4.1," AT",F4.1,"% CE55")
                WRITE(6,2425)T
          2425  FORMAT(T2,F4.1,T11,41("-"))
          2430  WRITE(6,2431)S(10,1),R(10,2)
          2431  FORMAT(T12,"TO DEPTH OF FILL,CBR=",F4.1," AT ",F4.1,"% C
   >>>>   E55",/
               C,"  TDF",7X,46("-"))
                T=R(6,4)-S(10,2)
                IF(T.LT.10.) GO TO 2465
                T=S(10,2)+5.
                WRITE(6,2455)T
          2455  FORMAT(T11,"6 INCHES,SCARIFY AND COMPACT IN PLACE AT",F5
   >>>>   .1,"% CE55
               C",/,T11,47("-"))
          2465  WRITE(6,2466)S(10,1),S(10,2)
          2466  FORMAT(T11,"CBR=",F4.1," IN-PLACE DENSITY=",F4.1,"% CE55
   >>>>   ",/,
               C60("*"),/,
               CT21,"FINAL DESIGN FOR CUT SECTIONS")
          C
          C     SUBROUTINE 2660
                CALL  FILLCUT(S,R,N,J1,K)
                L=6
                DO 2545 J=1,5
```

```
              J1=100-(J-1)*5
              IF(R(J,K).LE.R(L,3)) GO TO 2545
              IF(J1.LE.S(10,2)) GO TO 2550
              L=L+1
              ZGG=R(J,K)-R(L-1,3)
              IF(ZGG.LT.4.) GO TO 2535
              R(L,3)=R(J,K)
              GO TO 2540
        2535  R(L,3)=R(L-1,3)+4.
        2540  R(L,4)=J1
        2545  CONTINUE
        2550  ZHH=R(L,3)-R(L-1,3)
              IF(ZHH.LE.6.) GO TO 2560
              R(L-1,3)=R(L,3)-6.
        2560  DO 2610  J=7,L
              N=(R(J,3)-P)/2.-1.
        C
        C     SUBROUTINE 2635
              CALL  SPACER(N,P)
              IF(J.EQ.L) GO TO 2590
              WRITE(6,2580)R(J,4)
        2580  FORMAT(T11,"SUBGRADE REMOVED AND REPLACED AT ",F5.1,"% C
   >>>> E55")
              GO TO 2595
        2590  WRITE(6,2591)R(J,4)
        2591  FORMAT(T11,"SCARIFY AND COMPACT IN-PLACE AT ",F5.1,"% CE
   >>>> 55")
        2595  N=R(J,3)-P-1.
1 FTN 4.8+528         81/11/03. 09.30.59 PAGE      8
  SUBROUTINE BASE      73/74    TS

        C
        C     SUBROUTINE 2635
```

```
                 CALL SPACER(N,P)
                 WRITE(6,2605)R(J,3)
            2605  FORMAT(T2,F4.1,T11,36("-"))
            2610  CONTINUE
                 WRITE(6,2615)S(10,1),S(10,2)
            2615  FORMAT(T11,"CBR=",F4.1,5X,"IN PLACE DENSITY=",F5.1,"5 CE
     >>>>    55",/,
                C60("*"),/,
                C"THIS COMPLETES THE SOILS DESIGN")
                 RETURN
                 END

      45000B CM STORAGE USED          6.795 SECONDS
   1 FTN 4.8+528         81/11/03. 09.30.59 PAGE     1
     SUBROUTINE SPACER   73/74   TS

            C
            C
            C     SUBROUTINE 2635
                 SUBROUTINE SPACER(N,P)
                 DO 2645 IO=1,N
                 WRITE(6,2460)
            2460  FORMAT(/)
            2645  CONTINUE
                 ZII=N
                 P=P+ZII+1.
                 RETURN
                 END

      41000B CM STORAGE USED           .052 SECONDS
   1 FTN 4.8+528         81/11/03. 09.30.59 PAGE     1
     SUBROUTINE FILLCUT  73/74   TS

            C
            C      SUBROUTINE 2660
```

```
      SUBROUTINE FILLCUT(S,R,N,J1,K)
      DIMENSION S(10,6),R(20,4)
      J1=80
      WRITE(6,2670)
 2670 FORMAT(" DEPTH",/,
     C"(INCHES)",3X,14("="),"  TOP OF PAVEMENT",1X,14("="))
      IF(S(1,5).GT.1.) GO TO 2710
      IF(S(1,5).EQ.1.) GO TO 2695
      WRITE(6,2685)
 2685 FORMAT(T11,"SURFACE TREATMENT REQUIRED")
      GO TO 2700
 2695 WRITE(6,2696)
 2696 FORMAT(T11,"MULTIPLE SURFACE TREATMENT REQUIRED")
 2700 P=1.
      GO TO 2725
 2710 N=(S(1,5)/2.-1.)
C
C     SUBROUTINE 2635
      CALL SPACER(N,P)
      WRITE(6,2716)S(1,5)
 2716 FORMAT(T11,F4.1," INCHES OF ASPHALTIC PAVEMENT")
      N=S(1,5)-P
C
C     SUBROUTINE 2635
      CALL SPACER(N,P)
      WRITE(6,2720)S(1,5)
 2720 FORMAT(T2,F4.1,T11,36("-"))
 2725 DO 2960 I=2,8
      IF(S(I,1).EQ.0.0) GO TO 2960
      IF(S(I,1).LT.20.0) GO TO 2785
      N=(R(I,1)-P)/2.-1.
```

```
      C
      C       SUBROUTINE 2635
              CALL SPACER(N,P)
              WRITE(6,2750)S(I,5),S(I,1)
      2750    FORMAT(T11,F4.1," INCHES,CBR=",F5.1," AT 100% CE55")
              N=(R(I,1)-P-1.)
      C
      C       SUBROUTINE 2635
              CALL SPACER(N,P)
              WRITE(6,2765)R(I,1)
      2765    FORMAT(T2,F4.1,T11,36("-"))
              R(6,3)=R(I,1)
              R(6,4)=100.0
              GO TO 2960
      2785    L=6
              DO 2830 J=1,5
              J1=100-(J-1)*5
              IF(R(J,K).LT.R(L,3)) GO TO 2830
              IF(R(I,1).LT.R(J,K)) GO TO 2835
              IF(R(I,2).LE.J1) GO TO 2830
              L=L+1
              R(L,K)=R(J,3)
              R(L,4)=J1
      2830    CONTINUE
1 FTN 4.8+528        81/11/03. 09.30.59 PAGE      2
  SUBROUTINE FILLCUT  73/74    TS

      2835    L=L+1
              R(L,3)=R(I,1)
              IF(R(I,2).LT.J1) GO TO 2855
              R(L,4)=R(I,2)
              GO TO 2865
```

```
 2855  R(L,4)=J1
 2865  IKK=L-1
       DO 2885 J=6,IKK
       ZFINK=R(J+1,3)-R(J,3)
       IF(ZFINK.GE.4.) GO TO 2885
       LFINK=L-1
       IF(J.EQ.LFINK) GO TO 2895
       R(J+1,3)=R(J,3)+4.
 2885  CONTINUE
       GO TO 2905
 2895  R(J,3)=R(L,3)
       L=L-1
 2905  DO 2945 J=7,L
       K=(R(J,3)-P)/2.-1.
 C
 C     SUBROUTINE 2635
       CALL SPACER(N,P)
       T=R(J,3)-R(J-1,3)
       WRITE(6,2925)T,S(I,1),R(J,4)
 2925  FORMAT(T11,F4.1," INCHES,CBR=",F4.1," AT",F5.1,"% CE55")
       N=R(J,3)-P-1.
 C
 C     SUBROUTINE 2635
       CALL SPACER(N,P)
       WRITE(6,2940)R(J,3)
 2940  FORMAT(T2,F4.1,T11,36("-"))
 2945  CONTINUE
       R(6,3)=R(L,3)
       R(6,4)=R(L,4)
 2960  CONTINUE
       RETURN
       END

41000B CM STORAGE USED          .814 SECONDS
```

```
1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      1
  SUBROUTINE ELEV        73/74    TS    .

      C
      C     SUBROUTINE 4000
            SUBROUTINE ELEV(E,G,H)
            DIMENSION E(50,15),G(50),H(20,8)
            WRITE(6,4005)
      4005  FORMAT(//,"THIS SUBROUTINE WILL CALCULATE THE CENTERLINE
 >>>> ",/,
           C"ELEVATION OF THE FINISHED GRADE. YOU MUST SUPPLY THE",/
 >>>> ,
           C"ACTUAL ELEVATIONS OF THE LEFT SIDE DITCH BACKSLOPE,",/,
           C"CENTERLINE,AND THE RIGHT SIDE DITCH BACKSLOPE. THE",/,
           C"TERMINAL POINT FOR BACKSLOPES IS 28 FEET LEFT OR",/,
           C"RIGHT OF THE CENTERLINE. ENSURE THAT THE PC, PT, AND",/
 >>>> ,
           C"MIDPOINTS OF ANY CURVES IN THIS SECTION ARE INCLUDED.",
 >>>> //,
           C"HOW MANY STATIONS IN THIS SECTION? MAX=50",/)
            READ(5,4040)M
      4040  FORMAT(I2)
            DO 4100 I=1,M
            WRITE(6,4050)
      4050  FORMAT(/,"WHAT IS THE NEXT STATION NO.?")
            READ(5,4055)E(I,1)
      4055  FORMAT(F7.3)
            WRITE(6,4060)
      4060  FORMAT("IS THIS STATION A CURVE PC?",/,
           C"IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR",/,
           C"2 FOR RIGHT CURVE")
            READ(5,4065)IABLE
      4065  FORMAT(I1)
            E(I,6)=IABLE
            WRITE(6,4070)
      4070  FORMAT("WHAT IS CORRESPONDING ELEVATION LEFT SIDE?")
```

```
               READ(5,4075)E(I,2)
         4075  FORMAT(F7.3)
               WRITE(6,4080)
         4080  FORMAT("WHAT IS CORRESPONDING ELEVATION CENTERLINE?")
               READ(5,4085)E(I,3)
         4085  FORMAT(F7.3)
               WRITE(6,4090)
         4090  FORMAT("WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?")
               READ(5,4095)E(I,4)
         4095  FORMAT(F7.3)
         4100  CONTINUE
               DO 4115 I=1,M
               E(1,5)=0.0
               J=I+1
               E(J,5)=(E(J,3)-E(I,3))/(E(J,1)-E(I,1))
         4115  CONTINUE
               WRITE(6,4120)
         4120  FORMAT(/,T2,"STA NO",T15,"LS ELEV",T30,"CL ELEV",T45,"RS
 >>>>     ELEV",T60
              C,"SLOPE",/)
               DO 4140 I=1,M
               WRITE(6,4135)E(I,1),E(I,2),E(I,3),E(I,4),E(I,5)
         4135  FORMAT(T2,F7.3,T15,F7.3,T30,F7.3,T45,F7.3,T60,F7.3)
         4140  CONTINUE
1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      2
  SUBROUTINE ELEV       73/74    TS

               WRITE(6,4150)
         4150  FORMAT(/,"YOU MUST REVIEW THE SLOPE AND DETERMINE THE ",
 >>>>    /,
              C"DESIRED GRADE OR GRADES."/)
```

```
            M1=M-1
            DO 4567 I=1,M1
            G(I)=0.0
      4567  CONTINUE
            DO 4175 I=1,M1
            J=I+1
            WRITE(6,4165)E(I,1),E(J,1)
      4165  FORMAT("WHAT IS THE GRADE FROM ",F6.2," TO ",F6.2)
            READ(5,4170)G(I)
      4170  FORMAT(F7.3)
      4175  CONTINUE
      C
      C     CHANGED WORDING OF RRS PROGRAM LINE 04180
      C
            WRITE(6,4180)
      4180  FORMAT(/,"WHAT IS THE FINAL GRADE CENTERLINE ELEVATION",
>>>>  /,
           C"OF THE FIRST STATION ?")
            READ(5,4185)E(1,7)
      4185  FORMAT(F7.3)
            DO 4214 I=1,M1
            J=I+1
            E(J,7)=((E(J,1)-E(I,1))*G(I))+E(I,7)
      4214  CONTINUE
            I=1
      4220  JK=I+1
            IF(G(I).EQ.G(JK)) GO TO 4275
            WRITE(6,4221)E(JK,1)
      4221  FORMAT(/,"A VERTICAL CURVE IS NECESSARY AT STA ",F6.2)
            WRITE(6,4225)
      4225  FORMAT("HOW MANY STATIONS DO YOU WANT TO INCLUDE IN THE
```

```
>>>>    CURVE ?")
             READ(5,4230)B
        4230  FORMAT(F7.3)
        C
        C     CHANGED LOGIC OF RRS PROGRAM LINES 04220 TO
        C     04276 TO CORRECTLY COMPUTE CENTERLINE VERTICAL CURVE
        C
              VS=E(JK,1)
              ELEVVS=E(JK,7)
              ELEVC=ELEVVS-(G(I)*(B/2.))
        C     BVC=C,EVC=D,V=VS
              C=VS-(B/2.)
              D=VS+(B/2.)
              RGRAD=(G(JK)-G(I))/(B*2.)
              DO 4273 J=1,M
              IF(E(J,1).LT.C) GO TO 4273
              IF(E(J,1).GE.D) GO TO 4274
              XSTA=E(J,1)-C
              E(J,7)=((XSTA**2.)*RGRAD)+(G(I)*XSTA)+ELEVC
        4273  CONTINUE
        4274  I=J
        4275  I=I+1
1 FTN 4.8+528         81/11/03. 09.30.59 PAGE      3
  SUBROUTINE ELEV      73/74   TS

              IF(I.LT.M1) GO TO 4220
              WRITE(6,4290)
        4290  FORMAT(/,7X,32("*")," CROSS SECTION ",32("*"),//)
              I=1
              J=1
        4315  IF(E(I,6).EQ.0.0) GO TO 4725
              IF(H(J,8).EQ.0.0) GO TO 4725
```

```
      A=15.5*H(J,9)
      C=A/(H(J,5)/2.)
      Q=11.5*H(J,8)
      R=Q/(H(J,5)/2.)
      IF(E(I,6).EQ.2.) GO TO 4525
4345  HCUCH=H(J,6)+(H(J,5)/200.)
      IF(E(I,1).GT.HCUCH) GO TO 4410
      D=(E(I,1)-H(J,6))*C
      W=(E(I,1)-H(J,6))*R
      E(I,13)=E(I,7)+D
      E(I,12)=E(I,7)+W
      E(I,14)=E(I,13)-4.5*0.333
      E(I,15)=E(I,14)+8.1*0.275
      E(I,11)=E(I,7)-11.5*0.275
      E(I,10)=E(I,11)-4.0*0.63
      E(I,9)=E(I,10)-4.5*0.333
      E(I,8)=E(I,9)+8.1*0.275
      I=I+1
      GO TO 4345
4410  HIA=H(J,7)-(H(J,5)/200.)
      IF(E(I,1).GT.HIA) GO TO 4455
      E(I,13)=E(I,7)+A
      E(I,12)=E(I,7)+R
      E(I,14)=E(I,13)-4.5*0.333
      E(I,15)=E(I,14)+8.1*0.275
      E(I,10)=E(I,11)-4.0*0.063
      E(I,9)=E(I,10)-4.5*0.333
      E(I,8)=E(I,9)+8.1*0.275
      I=I+1
      GO TO 4410
4455  P=(H(J,7)-E(I,1))*C
      T=(H(J,7)-E(I,1))*R
      E(I,13)=E(I,7)+P
      E(I,12)=E(I,7)+T
      E(I,14)=E(I,13)-4.5*0.3333
      E(I,15)=E(I,14)+8.1*0.275
      E(I,11)=E(I,7)-11.5*0.042
```

```
          E(I,10)=E(I,11)-4.0*0.063
          E(I,9)=E(I,10)-4.5*0.333
          E(I,8)=E(I,9)+8.1*0.275
          I=I+1
          IF(E(I,1).LT.H(J,7)) GO TO 4455
          J=J+1
          GO TO 4315
    4525  HIB=H(J,6)+(H(J,5)/200.)
          IF(E(I,1).GT.HIB) GO TO 4595
          D=(E(I,1)-H(J,6))*C
          W=(E(I,1)-H(I,6))*R
          E(I,10)=E(I,7)+D
          E(I,11)=E(I,7)+W
1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      4
  SUBROUTINE ELEV       73/74    TS

          E(I,9)=E(I,10)-4.5*0.333
          E(I,8)=E(I,9)+8.1*0.275
          E(I,12)=E(I,7)-11.5*0.042
          E(I,13)=E(I,12)-4.0*0.063
          E(I,14)=E(I,13)-4.5*0.333
          E(I,15)=E(I,14)+8.1*0.275
          I=I+1
          GO TO 4525
    4595  HIC=H(J,7)-(H(J,5)/200.)
          IF(E(I,1).GT.HIC) GO TO 4650
          E(I,10)=E(I,7)+A
          E(I,11)=E(I,7)+R
          E(I,9)=E(I,10)-4.5*0.333
          E(I,8)=E(I,9)+8.1*0.275
          E(I,12)=E(I,7)-11.5*0.042
          E(I,13)=E(I,12)-4.0*0.063
          E(I,14)=E(I,13)-4.5*0.333
          E(I,15)=E(I,14)+8.1*0.275
```

```
            I=I+1
            GO TO 4595
      4650  P=(H(J,7)-E(I,1))*C
            T=(H(J,7)-E(I,1))*R
            E(I,10)=E(I,7)+P
            E(I,11)=E(I,7)+T
            E(I,9)=E(I,10)-4.5*0.333
            E(I,8)=E(I,9)+8.1*0.275
            E(I,12)=E(I,7)-11.5*0.042
            E(I,13)=E(I,12)-4.0*0.063
            E(I,14)=E(I,13)-4.5*0.333
            E(I,15)=E(I,14)+8.1*0.275
            I=I+1
      4710  IF(E(I,1).LT.H(J,7)) GO TO 4650
            J=J+1
            GO TO 4315
      4725  E(I,11)=E(I,7)-11.5*0.042
            E(I,10)=E(I,11)-4.0*0.063
            E(I,9)=E(I,10)-4.5*0.063
            E(I,8)=E(I,9)+8.1*0.275
            E(I,12)=E(I,7)-11.5*0.042
            E(I,13)=E(I,12)-4.0*0.063
            E(I,14)=E(I,13)-4.5*0.333
            E(I,15)=E(I,14)+8.1*0.275
            I=I+1
            MIZ=M+1
            IF(I.EQ.MIZ) GO TO 4780
            GO TO 4315
      4780  WRITE(6,4781)
      4781  FORMAT(T2,"STA",T22,"BACKL",T42,"DITL",T62,"SHL",T82,"PV
>>>>  MTL",T102,
           C"CL",/)
```

```
                 DO 4800 I=1,M
                 WRITE(6,4795)E(I,1),E(I,8),E(I,9),E(I,10),E(I,11),E(I,7)
          4795   FORMAT(T2,F7.3,T22,F7.3,T42,F7.3,T62,F7.3,T82,F7.3,T102,
    >>>>      F7.3)
          4800   CONTINUE
                 WRITE(6,4815)
          4815   FORMAT(//,T2,"STA",T22,"PVMTR",T42,"SHR",T62,"DITR",T82,
1 FTN 4.8+528         81/11/03. 09.30.59 PAGE      5
  SUBROUTINE ELEV      73/74    TS

    >>>>      "BACKR",/)
                 DO 4835 I=1,M
                 WRITE(6,4830)E(I,1),E(I,12),E(I,13),E(I,14),E(I,15)
          4830   FORMAT(T2,F7.3,T22,F7.3,T42,F7.3,T62,F7.3,T82,F7.3)
          4835   CONTINUE
                 CALL XSECT(E,M)
                 RETURN
                 END

     43000B CM STORAGE USED          3.828 SECONDS
1 FTN 4.8+528         81/11/03. 09.30.59 PAGE      1
  SUBROUTINE XSECT     73/74    TS

          C
          C      SUBROUTINE XSECT
          C
          C      THIS SUBROUTINE COMPUTES THE CROSS SECTIONAL AREA OF
          C      EACH STATION, AND OUTPUTS THE VOLUME AND CUCULATIVE
          C      VOLUME BETWEEN STATIONS. IT ALSO COORDINATES THE
          C      OUTPUTS OF THE INSECT AND MASBAL SUBROUTINES.
          C
                 SUBROUTINE XSECT(E,M)
```

```
C
C     THIS SUBROUTINE COMPUTES THE CROSS SECTIONAL AREA OF
C     EACH STATION, AND OUTPUTS THE VOLUME AND CUCULATIVE
C     VOLUME BETWEEN STATIONS. IT ALSO COORDINATES THE
C     OUTPUTS OF THE INSECT AND MASBAL SUBROUTINES.
C
      SUBROUTINE XSECT(E,M)
      DIMENSION E(50,15)
      DIMENSION INGR(50),INGL(50)
      DIMENSION XINSR(50,2),XINSL(50,2)
      DIMENSION YS(12),XS(12)
      DIMENSION XSA(50)
      DIMENSION VOL(50),CVOL(50)
      DIMENSION X(52),Y(52)
      DIMENSION YMAX(50)
      DIMENSION BUF(512)
      DATA YS(1),XS(2),XS(3),XS(4),XS(5),XS(6),XS(7),XS(8),XS(
     C9),XS(10),XS(12)/0.0,28.1,20.0,15.5,11.5,0.0,-11.5,-15.5
     C,-20.0,-28.1,0.0/
      CALL INSECT(E,M,XINSR,XINSL,INGR,INGL)
      DO 5000 J=1,M
      YS(2)=XINSL(J,1)-E(J,8)
      YS(3)=XINSL(J,1)-E(J,9)
      YS(4)=XINSL(J,1)-E(J,10)
      YS(5)=XINSL(J,1)-E(J,11)
      YS(6)=XINSL(J,1)-E(J,7)
      YS(7)=XINSL(J,1)-E(J,12)
      YS(8)=XINSL(J,1)-E(J,13)
      YS(9)=XINSL(J,1)-E(J,14)
      YS(10)=XINSL(J,1)-E(J,15)
      YS(11)=XINSL(J,1)-XINSR(J,1)
      YS(12)=XINSL(J,1)-E(J,3)
      XS(1)=XINSL(J,2)
```

```
           XS(11)=XINSR(J,2)*(-1.0)
           XSA(J)=(YS(12)*(XS(1)-XS(11)))+(YS(1)*(XS(2)-XS(12)))
           DO 5001 I=2,11
           NXSA=I+1
           MXSA=I-1
           XSA(J)=XSA(J)+(YS(I)*(XS(NXSA)-XS(MXSA)))
     5001  CONTINUE
           XSEXT=(XSA(J)/2.0)
           IF(XSEXT.GE.0.0) GO TO 5500
           XSA(J)=XSEXT*(-1.0)
           GO TO 5501
     5500  XSA(J)=XSEXT
     5501  IF(E(J,7).GT.E(J,3)) GO TO 5000
           XSA(J)=XSA(J)*(-1.0)
     5000  CONTINUE
           VOL(1)=0.0
           DO 5002 J=2,M
           VOL(J)=(XSA(J-1)+XSA(J))*(E(J,1)-E(J-1,1))*100.0/54.0
     5002  CONTINUE
           CVOL(1)=0.0
           SUM=0.0
           DO 5003 J=2,M
1 FTN 4.8+528        81/11/03. 09.30.59 PAGE      2
  SUBROUTINE XSECT     73/74    TS

           CVOL(J)=VOL(J)+SUM
           SUM=CVOL(J)
     5003  CONTINUE
           WRITE(6,5004)
     5004  FORMAT(///,51("="))
           WRITE(6,5005)
     5005  FORMAT("SUBROUTINE XSECT COMPUTES CROSS SECTIONAL AREAS"
 >>>>      ,/,
          C"FOR EACH STA, VOLUME BETWEEN STAS, AND CUMULATIVE",/,
          C"VOLUME. FILL AREAS ARE GIVEN A + SIGN AND CUT AREAS",/,
          C"ARE INDICATED BY A - SIGN.",//)
           WRITE(6,5006)
     5006  FORMAT(//,21("="),"  VOLUMES  ",21("="),//)
           WRITE(6,5007)
```

```
        5007  FORMAT(2X,"STA NO",2X,"CROSS SECTION",2X,"VOLUME BETWEEN
 >>>>   ",2X,"CUMU
             CLATIVE")
              WRITE(6,5008)
        5008  FORMAT(12X,"AREAS(SF)",5X,"STATIONS(CY)",3X,"VOLUME(CY)"
 >>>>   ,/)
              DO 5009 J=1,M
              WRITE(6,5010)VOL(J),CVOL(J)
        5010  FORMAT(27X,F10.2,4X,F10.2)
              WRITE(6,5011)E(J,1),XSA(J)
        5011  FORMAT(2X,F6.2,2X,F10.2)
        5009  CONTINUE
              WRITE(6,5012)
        5012  FORMAT(//,51("="))
              CALL MASBAL(E,M,CVOL)
              WRITE(6,5013)
        5013  FORMAT(///,61("*"))
              RETURN
              END

   41000B CM STORAGE USED           .799 SECONDS
1 FTN 4.8+528         81/11/03. 09.30.59 PAGE     1
  SUBROUTINE INSECT   73/74   TS

        C
        C     SUBROUTINE INSECT
        C
        C     THIS SUBROUTINE APPROXIMATES THE INTERSECTION
        C     POINT OF THE ROAD SIDESLOPES WITH THE
        C     EXISTING GROUND.  INPUT CONSISTS OF THE
        C     SIDESLOPE GRADE AT EACH STATION.
        C
              SUBROUTINE INSECT(E,M,XINSR,XINSL,INGR,INGL)
              DIMENSION E(50,15)
```

```
          DIMENSION XINSR(50,2),XINSL(50,2)
          DIMENSION INGR(50),INGL(50)
          DO 6010 I=1,M
          XINSR(I,1)=0.0
          XINSR(I,2)=0.0
          XINSL(I,1)=0.0
          XINSL(I,2)=0.0
    6010  CONTINUE
          WRITE(6,6011)
    6011  FORMAT(///,61("*"),///,56("="),/,
         C"SUBROUTINE INSECT COMPUTES THE INTERSECTION OF THE",/,
         C"SIDESLOPES WITH THE EXISTING GROUND AT EACH STA.",/,
         C"INPUT A SLOPE GRADE IN RESPONSE TO THE PROGRAMS QUESTIO
>>>>    NS.",/,
         C"USE ANY WHOLE NUMBER UP TO TWO DIGITS.",/,
         C"I.E.  USE 2 FOR 1:2 OR 4 FOR 1:4",//)
          DO 6012 J=1,M
    6017  WRITE(6,6013)E(J,1)
    6013  FORMAT("WHAT IS THE RIGHT SLOPE GRADE AT STA. ",F6.2,"?"
>>>>    )
          READ(5,6014)INGR(J)
    6014  FORMAT(I2)
          WRITE(6,6015)
    6015  FORMAT(/)
          TCA=INGR(J)
          IF(E(J,15).EQ.E(J,4)) GO TO 6025
          IF(E(J,15).LT.E(J,4)) GO TO 6021
          TCB=(E(J,3)-E(J,4))/28.1
          IF(TCB.NE.TCA) GO TO 6018
          WRITE(6,6016)
    6016  FORMAT("THE SLOPE GRADE CHOSEN IS PARRALLEL WITH",/,
         C"THE EXISTING GROUND. CHOOSE ANOTHER SLOPE GRADE.",/)
```

```
      GO TO 6017
 6018 I=1
 6019 XAI=I
      TCD=E(J,4)-(TCB*XAI)
      TCE=28.1+(TCA*XAI)
      TCF=E(J,15)-XAI
      IF(TCF.LE.TCD) GO TO 6020
      I=I+1
      GO TO 6019
 6020 XINSR(J,1)=TCD
      XINSR(J,2)=TCE
      GO TO 6012
 6021 TCC=(E(J,4)-E(J,3))/28.1
      IF(TCC.NE.TCA) GO TO 6023
      WRITE(6,6022)
1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      2
  SUBROUTINE INSECT    73/74   TS

 6022 FORMAT("THE SLOPE GRADE CHOSEN IS PARRALLEL WITH",/,
     C"THE EXISTING GROUND. CHOOSE ANOTHER SLOPE GRADE",/)
      GO TO 6017
 6023 I=1
 6024 XBI=I
      TCG=E(J,4)+(TCC*XBI)
      TCH=28.1+(TCA*XBI)
      TCI=E(J,15)+XBI
      IF(TCI.GE.TCG) GO TO 6026
      I=I+1
      GO TO 6024
 6026 XINSR(J,1)=TCI
      XINSR(J,2)=TCH
      GO TO 6012
 6025 XINSR(J,1)=E(J,15)
      XINSR(J,2)=28.1
 6012 CONTINUE
      DO 6030  J=1,M
 6031 WRITE(6,6032)E(J,1)
```

```
6032  FORMAT("WHAT IS THE LEFT SLOPE GRADE AT STA. ",F6.2,"?")
      READ(5,6034)INGL(J)
6034  FORMAT(I2)
      WRITE(6,6035)
6035  FORMAT(/)
      TCAA=INGL(J)
      IF(E(J,8).EQ.E(J,2)) GO TO 6045
      IF(E(J,8).LT.E(J,4)) GO TO 6040
      TCJ=(E(J,3)-E(J,2))/28.1
      IF(TCJ.NE.TCAA) GO TO 6037
      WRITE(6,6036)
6036  FORMAT("THE SLOPE GRADE CHOSEN IS PARRALLEL WITH",/,
     C"THE EXISTING GROUND. CHOOSE ANOTHER SLOPE GRADE.",/)
      GO TO 6031
6037  I=1
6038  XCI=I
      TCL=E(J,2)-(TCJ*XCI)
      TCM=28.1+(TCAA*XCI)
      TCN=E(J,8)-XCI
      IF(TCN.LE.TCL) GO TO 6039
      I=I+1
      GO TO 6038
6039  XINSL(J,1)=TCL
      XINSL(J,2)=TCM
      GO TO 6030
6040  TCK=(E(J,2)-E(J,3))/28.1
      IF(TCK.NE.TCAA) GO TO 6042
      WRITE(6,6041)
6041  FORMAT("THE SLOPE GRADE CHOSEN IS PARRALLEL WITH",/,
     C"THE EXISTING GROUND. CHOSE ANOTHER SLOPE GRADE.",/)
      GO TO 6031
```

```
      6042  I=1
      6043  XDI=I
            TCO=E(J,2)+(TCK*XDI)
            TCP=28.1+(TCAA*XDI)
            TCQ=E(J,8)+XDI
            IF(TCQ.GE.TCO) GO TO 6044
            I=I+1
1 FTN 4.8+528         81/11/03. 09.30.59 PAGE      3
  SUBROUTINE INSECT    73/74    TS

            GO TO 6043
      6044  XINSL(J,1)=TCQ
            XINSL(J,2)=TCP
            GO TO 6030
      6045  XINSL(J,1)=E(J,8)
            XINSL(J,2)=28.1
      6030  CONTINUE
            WRITE(6,6050)
      6050  FORMAT(//,18("="),"  INTERSECTION POINTS ",17("="),//)
            WRITE(6,6051)
      6051  FORMAT(2X,"STA NO",4X," LEFT HAND SIDESLOPE",4X,"RIGHT H
 >>>>   AND SIDESL
           COPE")
            WRITE(6,6052)
      6052  FORMAT(13X,"GRADE   ELEV    DIST",6X,"GRADE   ELEV    DIST",
 >>>>   /)
            DO 6053  J=1,M
            WRITE(6,6054)E(J,1),INGL(J),XINSL(J,1),XINSL(J,2),INGR(J
 >>>>   ),XINSR(J,
           C1),XINSR(J,2)
      6054  FORMAT(2X,F6.2,6X,I2,2X,F6.2,1X,F6.2,7X,I2,2X,F6.2,1X,F6
```

```
>>>>    ,2)
        6053  CONTINUE
              WRITE(6,6060)
        6060  FORMAT(//,56("="))
              RETURN
              END

   42000B CM STORAGE USED          1.575 SECONDS
 1 FTN 4.8+528         81/11/03. 09.30.59 PAGE     1
   SUBROUTINE MASBAL   73/74   TS

        C
        C     SUBROUTINE MASBAL
        C
        C     THIS SUBROUTINE COMPUTES THE MAXIMUM
        C     AND MINIMUM VOLUMES AND IDENTIFIES THEIR
        C     STATION LOCATION.  IT ALSO PLOTS A
        C     MASS DIAGRAM ON THE VERSATEC PLOTTER.
        C
              SUBROUTINE MASBAL(E,M,CVOL)
              DIMENSION E(50,15),CVOL(50)
              DIMENSION X(52),Y(52),YMAX(50)
              DIMENSION BUF(512)
              DO 8800 J=1,M
              X(J)=E(J,1)
              Y(J)=CVOL(J)
        8800  CONTINUE
              DO 8900 J=1,M
              Y(J)=Y(J)+(1000000.0)
        8900  CONTINUE
              I=1
```

```
8810  AMAX=Y(1)
      K=1
      J=2
8808  IF(Y(J).LT.AMAX) GO TO 8805
      AMAX=Y(J)
      K=J
8805  IF(J.EQ.M) GO TO 8806
      GO TO 8807
8806  YMAX(I)=AMAX
      Y(K)=AMAX
      Y(K)=0.0
      GO TO 8809
8807  J=J+1
      GO TO 8808
8809  IF(I.EQ.M) GO TO 8811
      I=I+1
      GO TO 8810
8811  DO 8901 J=1,M
      Y(J)=YMAX(J)-(1000000.0)
8901  CONTINUE
      WRITE(6,8700)
8700  FORMAT(///,60("="))
      WRITE(6,8701)
8701  FORMAT("SUBROUTINE MASBAL FINDS MAXIMUM AND MINIMUM",/,
     C"CUMULATIVE VOLUMES, AND IDENTIFIES THEIR STATION",/,
     C"LOCATION POINTS. IT ALSO PLOTS A MASS DIAGRAM ON",/,
     C"THE VERSATEC PLOTTER, NO INPUT IS NECESSARY.",//)
      J=1
      YMAX(1)=YMAX(1)-(1000000.0)
8851  IF(YMAX(1).EQ.Y(J)) GO TO 8850
      J=J+1
      GO TO 8851
8850  WRITE(6,8852)Y(J),X(J)
8852  FORMAT("THE MAXIMUM CUMULATIVE VOLUME IS",F10.2," CUBIC
>>>> YARDS",/,
```

```
              C"THIS OCCURS AT STATION ",F6.2,/)
               J=1
1 FTN 4.8+528          81/11/03. 09.30.59 PAGE      2
  SUBROUTINE MASBAL    73/74    TS

               YMAX(M)=YMAX(M)-(1000000.0)
         8854  IF(YMAX(M).EQ.Y(J)) GO TO 8853
               J=J+1
               GO TO 8854
         8853  WRITE(6,8855)Y(J),X(J)
         8855  FORMAT("THE MINIMUM CUMULATIVE VOLUME IS",F10.2," CUBIC
   >>>>  YARDS",/,
              C"THIS OCCURS AT STATION ",F6.2,/)
               DO 8799 I=1,M
               Y(J)=Y(J)/1000.
         8799  CONTINUE
         C     OPEN THE PLOTFILE AND EXPAND PAGE LIMITS
               CALL PLOTS (BUF,512,9,00)
               CALL PLOTMX (55.)
         C     SCALE THE INPUT TO THE PAPER SIZE (6" X 50")
               CALL SCALE (X,50.,50,1)
               CALL SCALE (Y,6.,50,1)
         C     PLOT AND NAME THE AXIS
               CALL AXIS (1.,1.,"1000 CUBIC YARDS",16,6.,90.,Y(51),Y(52
   >>>>  ))
               CALL AXIS (1.,1.,"STATIONS",-8,50.,0.,X(51),X(52))
         C     PLOT ARRAY
               CALL LINE (X,Y,50,1,-1,3)
         C     CLOSE FILE
               CALL PLOT (0.,0.,999)
               WRITE(6,9950)
         9950  FORMAT(//,"GO TO THE PLOTTER BIN AND REMOVE OUTPUT (MASS
   >>>>   DIAGRAM)"
              C,//)
```

```
            CALL SCALE (X,50.,50,1)
            CALL SCALE (Y,6.,50,1)
      C     PLOT AND NAME THE AXIS
            CALL AXIS (1.,1.,"1000 CUBIC YARDS",16,6.,90.,Y(51),Y(52
>>>>  ))
            CALL AXIS (1.,1.,"STATIONS",-8,50.,0.,X(51),X(52))
      C     PLOT ARRAY
            CALL LINE (X,Y,50,1,-1,3)
      C     CLOSE FILE
            CALL PLOT (0.,0.,999)
            WRITE(6,8950)
      8950  FORMAT(//,"GO TO THE PLOTTER BIN AND REMOVE OUTPUT (MASS
>>>>   DIAGRAM)"
           C,//)
            WRITE(6,8951)
      8951  FORMAT(/,60("="))
            RETURN
            END

 41000B CM STORAGE USED            .684 SECONDS
 15.783 CP SECONDS COMPILATION TIME
```

APPENDIX F

SAMPLE OUTPUT

```
/OLD,FIRD
/ATTACH,CALCOMP/UN=LIBRARY
/LIBRARY(CALCOMP)
LIBRARY(CALCOMP)
/FTN,I=FIRD,L=0,TS
    15.941 CP SECONDS COMPILATION TIME
/LGO.


              ********************************* ROAD DESIGN *********************************


THIS PROGRAM IS A SERIES OF SUBROUTINES DESIGNED
TO ASSIST THE ENGINEER IN A MILITARY ROAD DESIGN.
THE OPERATION OF THE PROGRAM IS INTERACTIVE,
AND REQUIRES THE USE OF THE USERS MANUAL.


                                            HORIZONTAL ALIGNMENT


ENTER NO. OF CURVES THIS SECTION
?  1


ENTER STA NO OF TANGENT INTERSECTION OF CURVE  1
? 133.0


ENTER ANGLE OF INTERSECTION OF CURVE IN DEGREES
? 26.0


ENTER CHORD LENGTH IN FEET
? 600.0


         STA NO.    RAD      L OF C         D OF C         TAN LEN   PC STA    PT STA

        132.947    1333.62   605.181        9.46705        307.891   129.921   139.052
```

```
                                    SUPERELEVATION SUPERL

WHAT IS DESIGN VELOCITY OF CURVE  1
? 60
        STA NO      RAD       L OF C          SUPERL          TAN LEN    PC STA     PT STA

        132.947     1333.62   605.181        .04996069        307.891    129.921    139.052


WHAT DESIGN INDEX IS TO BE USED?
? 6
WHAT IS THE IN-PLACE (%CE55) OF THE SUBGRADE?
? 70.0
WHAT IS THE CBR OF THE SUBGRADE AT 90% TO 95% CE55?
? 5.0
HOW MANY TYPES OF BASE, SUBBASE, AND SELECT MATERIALS
DO YOU WISH TO CONSIDER?( DO NOT INCLUDE SUBGRADE OR PAVT)
? 3
WHAT IS THE CBR VALUE OF THE BASE COURSE?
? 82.0
WHAT IS THE NEXT HIGHEST CBR?
? 56.0
WHAT IS THE NEXT HIGHEST CBR?
? 43.0
WHAT CLASSIFICATION IS TO BE USED?
A=1,B=2,C=3,D=4,E=5,F=6
? 3
```

```
MIN THICKNESS RQD ABOVE SOIL WITH CBR= 5.0 IS 22.0
MIN THICKNESS RQD ABOVE SOIL WITH CBR=43.0 IS  4.0
MIN THICKNESS RQD ABOVE SOIL WITH CBR=56.0 IS  3.0
THE MIN RQD THICKNESS OF PAVT IS 3.0
MIN RQD THICKNESS OF BASE COURSE IS 4 INCHES
************************************************************

                      DESIGN PROFILE
 DEPTH
(INCHES)
    0            ======= TOP OF PAVEMENT =======


                3.0 INCHES OF ASPHALTIC PAVEMENT


  3.0      ------------------------------------




                4.0 INCHES OF BASE COURSE             CBR=82.0




  7.0      ------------------------------------




                4.0 INCHES OF SUBBASE MATERIAL        CBR=56.0




 11.0      ------------------------------------
```

```
               11.0 INCHES OF SELECT MATERIAL         CBR=43.0



 22.0      ------------------------------------
                     SUBGRADE                         CBR= 5.0
************************************************************
IF THE SUBGRADE IS COHESIVE(PI>5),TYPE 3
IF THE SUBGRADE IS NON-COHESIVE,TYPE 4.
? 4
************************************************************
         COMPACTION REQUIREMENTS (WRITTEN)

DEPTH
(INCHES)       ======= TOP OF PAVEMENT =======


              100.0% CBR=82.0



   7.0   ------------------------------------

              100.0% CBR=56.0

  11.0   ------------------------------------
```

```
                 100.0% CBR=43.0







 22.0    -------------------------------------
                 95.0% CBR= 5.0
                TOP (TO DEPTH OF FILL)

**************************************************************
                      FINAL DESIGN
                    FOR FILL SECTIONS
 DEPTH
(INCHES)   ============== TOP OF PAVEMENT ===============


           3.0 INCHES OF ASPHALTIC PAVEMENT



 3.0        -------------------------------------

           4.0 INCHES,CBR= 82.0 AT 100% LESS

 7.0        -------------------------------------

           4.0 INCHES,CBR= 56.0 AT 100% LESS

11.0        -------------------------------------
```

```
          11.0 INCHES,CBR= 43.0 AT 100% CE55





 22.0     ------------------------------------
           TO DEPTH OF FILL,CBR= 5.0 AT 95.0% CE55
  TOF       ----------------------------------------------
          6 INCHES,SCARIFY AND COMPACT IN PLACE AT 75.0% CE55
          -----------------------------------------------
          CBR= 5.0 IN-PLACE DENSITY=70.0% CE55
************************************************************
                    FINAL DESIGN FOR CUT SECTIONS
 DEPTH
(INCHES)   ============= TOP OF PAVEMENT ==============

           3.0 INCHES OF ASPHALTIC PAVEMENT


  3.0     ------------------------------------


           4.0 INCHES,CBR= 82.0 AT 100% CE55


  7.0     ------------------------------------


           4.0 INCHES,CBR= 56.0 AT 100% CE55


 11.0     ------------------------------------





          11.0 INCHES,CBR= 43.0 AT 100% CE55
```

```
22.0     ----------------------------------------

         SUBGRADE REMOVED AND REPLACED AT 100.0% CE55

28.0     ----------------------------------------



         SUBGRADE REMOVED AND REPLACED AT  95.0% CE55



40.0     ----------------------------------------
```

```
          SUBGRADE REMOVED AND REPLACED AT  90.0% CE55







 60.0     ------------------------------------


          SCARIFY AND COMPACT IN-PLACE AT  85.0% CE55



 66.0     ------------------------------------
          CBR= 5.0     IN PLACE DENSITY= 70.05 CE55
************************************************************
THIS COMPLETES THE SOILS DESIGN

THIS SUBROUTINE WILL CALCULATE THE CENTERLINE
ELEVATION OF THE FINISHED GRADE. YOU MUST SUPPLY THE
ACTUAL ELEVATIONS OF THE LEFT SIDE DITCH BACKSLOPE,
CENTERLINE,AND THE RIGHT SIDE DITCH BACKSLOPE. THE
TERMINAL POINT FOR BACKSLOPES IS 28 FEET LEFT OR
RIGHT OF THE CENTERLINE. ENSURE THAT THE PC, PT, AND
MIDPOINTS OF ANY CURVES IN THIS SECTION ARE INCLUDED.
```

```
HOW MANY STATIONS IN THIS SECTION? MAX=50

? 16

WHAT IS THE NEXT STATION NO.?
? 127.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 15.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 15.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 14.0

WHAT IS THE NEXT STATION NO.?
? 128.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 15.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 15.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 14.0

WHAT IS THE NEXT STATION NO.?
? 129.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 16.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 16.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 16.0

WHAT IS THE NEXT STATION NO.?
? 129.92
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 2
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 16.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 16.9
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 18.0
```

```
WHAT IS THE NEXT STATION NO.?
? 130.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 17.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 17.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 15.0

WHAT IS THE NEXT STATION NO.?
? 131.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 17.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 17.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 16.0

WHAT IS THE NEXT STATION NO.?
? 132.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 17.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 19.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 17.0

WHAT IS THE NEXT STATION NO.?
? 133.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 10.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 20.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 17.0
```

```
WHAT IS THE NEXT STATION NO.?
? 134.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 19.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 21.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 19.0

WHAT IS THE NEXT STATION NO.?
? 135.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 20.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 20.5
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 21.0

WHAT IS THE NEXT STATION NO.?
? 136.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 20.5
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 20.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 21.0

WHAT IS THE NEXT STATION NO.?
? 137.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 19.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 19.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 20.0
```

```
WHAT IS THE NEXT STATION NO.?
? 138.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 18.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 18.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 19.0

WHAT IS THE NEXT STATION NO.?
? 139.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 17.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 18.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 18.0

WHAT IS THE NEXT STATION NO.?
? 140.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 17.0
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 18.0
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 18.0

WHAT IS THE NEXT STATION NO.?
? 141.0
IS THIS STATION A CURVE PC?
IF NO ENTER 0, IF YES ENTER 1 FOR LEFT CURVE  OR
2 FOR RIGHT CURVE
? 0
WHAT IS CORRESPONDING ELEVATION LEFT SIDE?
? 18.5
WHAT IS CORRESPONDING ELEVATION CENTERLINE?
? 18.5
WHAT IS CORRESPONDIND ELEVATION RIGHT SIDE?
? 17.5
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 STA NO         LS ELEV           CL ELEV           RS ELEV           SLOPE

 127.000         15.000            15.000            14.000            0.000
 128.000         15.000            15.000            14.000            0.000
 129.000         16.000            16.000            16.000            1.000
 129.920         16.000            16.900            18.000             .978
 130.000         17.000            17.000            15.000            1.250
 131.000         17.000            17.000            16.000            0.000
 132.000         17.000            19.000            17.000            2.000
 133.000         10.000            20.000            17.000            1.000
 134.000         19.000            21.000            19.000            1.000
 135.000         20.000            20.500            21.000            -.500
 136.000         20.500            20.000            21.000            -.500
 137.000         19.000            19.000            20.000           -1.000
 138.000         18.000            18.000            19.000           -1.000
 139.000         17.000            18.000            18.000            0.000
 140.000         17.000            18.000            18.000            0.000
 141.000         18.500            18.500            17.500             .500

YOU MUST REVIEW THE SLOPE AND DETERMINE THE
DESIRED GRADE OR GRADES.

WHAT IS THE GRADE FROM 127.00 TO 128.00
? 1.0
WHAT IS THE GRADE FROM 128.00 TO 129.00
? 1.0
WHAT IS THE GRADE FROM 129.00 TO 129.92
? 1.0
WHAT IS THE GRADE FROM 129.92 TO 130.00
? 1.0
WHAT IS THE GRADE FROM 130.00 TO 131.00
? 1.0
WHAT IS THE GRADE FROM 131.00 TO 132.00
? -0.5
WHAT IS THE GRADE FROM 132.00 TO 133.00
? -0.5
WHAT IS THE GRADE FROM 133.00 TO 134.00
? -0.5
```

```
WHAT IS THE GRADE FROM 134.00 TO 135.00
? -0.5
WHAT IS THE GRADE FROM 135.00 TO 136.00
? -0.5
WHAT IS THE GRADE FROM 136.00 TO 137.00
? -0.5
WHAT IS THE GRADE FROM 137.00 TO 138.00
? 0.0
WHAT IS THE GRADE FROM 138.00 TO 139.00
? 0.0
WHAT IS THE GRADE FROM 139.00 TO 140.00
? 0.0
WHAT IS THE GRADE FROM 140.00 TO 141.00
? 0.0

WHAT IS THE FINAL GRADE CENTERLINE ELEVATION
OF THE FIRST STATION ?
? 15.0

A VERTICAL CURVE IS NECESSARY AT STA 131.00
HOW MANY STATIONS DO YOU WANT TO INCLUDE IN THE CURVE ?
? 2.0

A VERTICAL CURVE IS NECESSARY AT STA 137.00
HOW MANY STATIONS DO YOU WANT TO INCLUDE IN THE CURVE ?
? 4.0
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****************************** CROSS SECTION ******************************

STA            BACKL          DITL           SHL            PVMTL          CL

127.000         16.209         13.982         14.265         14.517         15.000
128.000         17.209         14.982         15.265         15.517         16.000
129.000         18.209         15.982         16.265         16.517         17.000
129.920         19.129         16.902         17.185         17.437         17.920
130.000         19.209         16.982         17.265         17.517         18.000
131.000         19.834         17.607         17.890         18.142         18.625
132.000         19.709         17.482         17.765         18.017         18.500
133.000         19.209         16.982         17.265         17.517         18.000
134.000         18.709         16.482         16.765         17.017         17.500
135.000         18.209         15.982         16.265         16.517         17.000
136.000         17.772         15.544         15.828         16.080         16.563
137.000         17.459         15.232         15.515         15.767         16.250
138.000         17.272         15.044         15.328         15.580         16.063
139.000         17.209         14.982         15.265         15.517         16.000
140.000         17.209         14.982         15.265         15.517         16.000
141.000         17.209         14.982         15.265         15.517         16.000

STA            PVMTR          SHR            DITR           BACKR

127.000         14.517         14.265         12.767         14.994
128.000         15.517         15.265         13.767         15.994
129.000         16.517         16.265         14.767         16.994
129.920         17.437         17.185         15.687         17.914
130.000         17.517         17.265         15.767         17.994
131.000         18.142         17.890         16.392         18.619
132.000         18.017         17.765         16.267         18.494
133.000         17.517         17.265         15.767         17.994
134.000         17.017         16.765         15.267         17.494
135.000         16.517         16.265         14.767         16.994
136.000         16.080         15.828         14.329         16.557
137.000         15.767         15.515         14.017         16.244
138.000         15.580         15.328         13.829         16.057
139.000         15.517         15.265         13.767         15.994
140.000         15.517         15.265         13.767         15.994
141.000         15.517         15.265         13.767         15.994

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SUBROUTINE INSECT COMPUTES THE INTERSECTION OF THE
SIDESLOPES WITH THE EXISTING GROUND AT EACH STA.
INPUT A SLOPE GRADE IN RESPONSE TO THE PROGRAMS QUESTIONS.
USE ANY WHOLE NUMBER UP TO TWO DIGITS.
I.E.  USE 2 FOR 1:2 OR 4 FOR 1:4


WHAT IS THE RIGHT SLOPE GRADE AT STA. 127.00?
?  3


WHAT IS THE RIGHT SLOPE GRADE AT STA. 128.00?
?  3


WHAT IS THE RIGHT SLOPE GRADE AT STA. 129.00?
?  3


WHAT IS THE RIGHT SLOPE GRADE AT STA. 129.92?
?  3


WHAT IS THE RIGHT SLOPE GRADE AT STA. 130.00?
?  2


WHAT IS THE RIGHT SLOPE GRADE AT STA. 131.00?
?  2


WHAT IS THE RIGHT SLOPE GRADE AT STA. 132.00?
?  2


WHAT IS THE RIGHT SLOPE GRADE AT STA. 133.00?
?  2


WHAT IS THE RIGHT SLOPE GRADE AT STA. 134.00?
?  2


WHAT IS THE RIGHT SLOPE GRADE AT STA. 135.00?
?  2
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WHAT IS THE RIGHT SLOPE GRADE AT STA. 136.00?
?  2

WHAT IS THE RIGHT SLOPE GRADE AT STA. 137.00?
?  2

WHAT IS THE RIGHT SLOPE GRADE AT STA. 138.00?
?  2

WHAT IS THE RIGHT SLOPE GRADE AT STA. 139.00?
?  2

WHAT IS THE RIGHT SLOPE GRADE AT STA. 140.00?
?  2

WHAT IS THE RIGHT SLOPE GRADE AT STA. 141.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 127.00?
?  3

WHAT IS THE LEFT SLOPE GRADE AT STA. 128.00?
?  3

WHAT IS THE LEFT SLOPE GRADE AT STA. 129.00?
?  3

WHAT IS THE LEFT SLOPE GRADE AT STA. 129.92?
?  3

WHAT IS THE LEFT SLOPE GRADE AT STA. 130.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 131.00?
?  2
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WHAT IS THE LEFT SLOPE GRADE AT STA. 132.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 133.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 134.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 135.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 136.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 137.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 138.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 139.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 140.00?
?  2

WHAT IS THE LEFT SLOPE GRADE AT STA. 141.00?
?  2
```

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================== INTERSECTION POINTS ==================

  STA NO      LEFT HAND SIDESLOPE     RIGHT HAND SIDESLOPE
              GRADE  ELEV    DIST      GRADE  ELEV    DIST

  127.00        3   15.00   34.10        3   13.93   34.10
  128.00        3   15.00   37.10        3   13.89   37.10
  129.00        3   16.00   37.10        3   16.00   31.10
  129.92        3   15.87   40.10        3   18.91   31.10
  130.00        2   17.00   34.10        2   14.72   36.10
  131.00        2   17.00   34.10        2   15.89   34.10
  132.00        2   16.79   34.10        2   16.86   32.10
  133.00        2    4.66   58.10        2   16.79   32.10
  134.00        2   19.71   30.10        2   19.49   32.10
  135.00        2   20.21   32.10        2   21.99   38.10
  136.00        2   20.77   34.10        2   21.56   38.10
  137.00        2   19.46   32.10        2   20.24   36.10
  138.00        2   18.27   30.10        2   20.06   36.10
  139.00        2   18.21   30.10        2   18.99   34.10
  140.00        2   18.21   30.10        2   18.99   34.10
  141.00        2   19.21   32.10        2   17.99   32.10

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SUBROUTINE XSECT COMPUTES CROSS SECTIONAL AREAS
FOR EACH STA, VOLUME BETWEEN STAS, AND CUMULATIVE
VOLUME. FILL AREAS ARE GIVEN A + SIGN AND CUT AREAS
ARE INDICATED BY A - SIGN.
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===================== VOLUMES ========================

  STA NO  CROSS SECTION  VOLUME BETWEEN  CUMULATIVE
           AREAS(SF)     STATIONS(CY)    VOLUME(CY)

                              0.00          0.00
  127.00     -10.69
                             85.41         85.41
  128.00      56.81
                            176.10        261.52
  129.00      38.28
                            114.66        376.18
  129.92      29.02
                             14.60        390.78
  130.00      69.55
                            297.11        687.89
  131.00      90.88
                            159.29        847.18
  132.00      -4.87
                           -199.79        647.39
  133.00    -103.02
                           -553.85         93.54
  134.00    -196.05
                           -853.92       -760.38
  135.00    -265.06
                          -1007.80      -1768.18
  136.00    -279.15
                           -927.93      -2696.11
  137.00    -221.93
                           -743.30      -3439.41
  138.00    -179.45
                           -638.72      -4078.13
  139.00    -165.46
                           -612.82      -4690.94
  140.00    -165.46
                           -640.29      -5331.23
  141.00    -180.30

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SUBROUTINE MASBAL FINDS MAXIMUM AND MINIMUM
CUMULATIVE VOLUMES, AND IDENTIFIES THEIR STATION
LOCATION POINTS. IT ALSO PLOTS A MASS DIAGRAM ON
THE VERSATEC PLOTTER, NO INPUT IS NECESSARY.


THE MAXIMUM CUMULATIVE VOLUME IS    847.18 CUBIC YARDS
THIS OCCURS AT STATION 127.00
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THE MINIMUM CUMULATIVE VOLUME IS  -5331.23 CUBIC YARDS
THIS OCCURS AT STATION 141.00



GO TO THE PLOTTER BIN AND REMOVE OUTPUT (MASS DIAGRAM)



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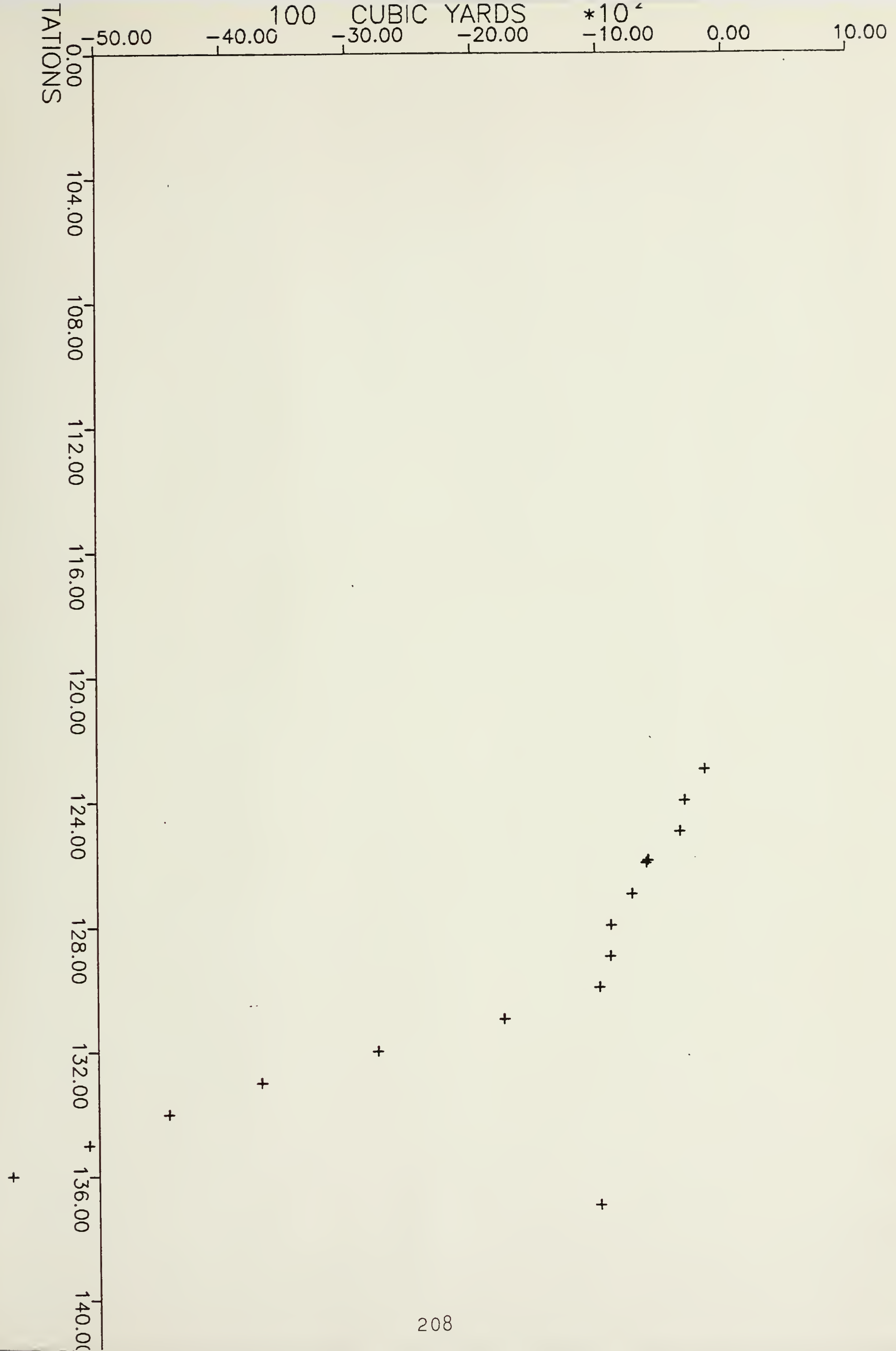
THIS PROGRAM WILL END
     3.232 CP SECONDS EXECUTION TIME.
/PLOTCV(TAPE9)
 PLOT.     81/11/03. 12.21.35.
/BYE

CE513AA   LOG OFF    12.23.00.
CE513AA   SRU     54.444 UNTS.
```


100 CUBIC YARDS *10²
-50.00
-40.00
-30.00
-20.00
-10.00
0.00
10.00
TATIONS
0.00
104.00
108.00
112.00
116.00
120.00
124.00
128.00
132.00
136.00
140.0

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c.1
FORTRAN interactive
road design.

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